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SCAN-CONVERSION STORAGE TUBE BASED UPON THE PERMACHON

Final Report

1 July 1960 to 31 December 1962

Contract No. DA36-039-sc-85051

Department of Army Task No. 3A99-13-003-03

U. S. Army Electronics Research and Development Laboratory
Fort Monmouth, New Jersey

943 800

WESTINGHOUSE ELECTRIC CORPORATION
ELECTRONIC TUBE DIVISION
ELMIRA NEW YORK

$6.60

Final Report
1 July 1960 to 31 December 1962

Objective: To study, conduct experimental investigations, and develop feasibility models of a scan-conversion storage tube utilizing electrical write-read transformation, wherein a photoconductive target similar to that of the Permachon will be used as the storage mechanism.

Contract No. DA36-039-sc-85051
Technical Requirements: Technical Guidelines dated 1 April 1960
Department of Army Task No. 3A99-13-003-03

R. J. Doyle

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PURPOSE

The purpose of this contract is to establish feasibility and demonstrate models of an electrical-input, electrical-output scan-conversion storage tube based upon a photoconductive readout target similar in principle to that used in the Westinghouse Electric Corporation's Permachon camera storage tube, to meet the objective specifications given in the Technical Guidelines dated 1 April 1960 of the Electronic Components Department, USAELRDL, titled "Research and Development of a Scan-Conversion Storage Tube Based Upon the Permachon."

ABSTRACT

A scan-conversion tube based upon the storage characteristics of the Permachon camera storage tube was developed by the Westinghouse Electric Corporation under this contract from the United States Army Electronics Research and Development Laboratory. The tube consists of three major components; a reading electron gun, a writing electron gun, and an interjacent scan-conversion target.

Two types of targets were investigated for use in the tube; those based upon: 1. Electron Bombardment Induced Conductivity (EBIC), 2. Fiber Optics Photon Transfer (FOPT).

The EBIC targets, in general, did not exhibit the storage, signal integration, and erasure characteristics of the Permachon storage surface, and, except for the aluminum-supported EBIC targets, high dark-current was a major problem.

The FOPT target, on the other hand, did perform similarly to a Permachon storage surface, and details of the characteristics of these targets are included in this report.

The final scan-conversion tube developed is 16 inches long; the read-gun is similar to a low-velocity vidicon gun; the write-gun is a high-velocity cathode ray tube gun; and the target is that based upon FOPT.

Because the written and read-out signals are isolated by the glass fiber-optics disc, no rf or other video-canceling circuitry is required for the operation of the tube.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

Listed below are the publications, lectures, reports, and conferences resulting from the research and development of this contract.

Publications	- None
Lectures	- None
Reports	- 10 monthly progress reports by W. S. Rial
	- 8 monthly progress reports by R. J. Doyle
	- 6 quarterly reports by W. S. Rial
	- 3 quarterly reports by R. J. Doyle
Conferences	- The Contracting Officer's Technical Representative, Mr. M. E. Crost, visited the Image Tube Department of the Westinghouse Electric Corporation on 13 Oct 60, 28 Feb 61, 27 Jun 51, 2 Nov 61, 20 Mar 62, 5 July 62, and 16 Oct 62, to review the contract.
	- Mr. G. Bernhardt of the Westinghouse Research Laboratory visited the Image Tube Department on 27 Jun 61 to discuss EBIConductor support-film fabrication.
	- Mr. L. G. Bonney of the Image Tube Department visited the Westinghouse Research Laboratory on 13 Feb 62 to consult with Mr. J. Lempert on the status of EBIC target development.

FACTUAL DATA

INTRODUCTION

The scan-converter tube is an electron device into which information can be introduced in one format and extracted simultaneously or at a later time in the same or a different format.

The Permahon-type scan-converter developed during this program is shown in Figure 1; it consists basically of a small cathode-ray tube, an interjacent target, and a vidicon. The cathode-ray portion of the tube generates a high-velocity electron beam that is modulated and deflected to generate a written pattern of information. The target used can be one of many types, yet its basic function is to store the written information for some period of time, from fractions of a second to hours. The vidicon section serves to generate a low-velocity unmodulated electron beam which scans the opposite side of the target and reads out the stored information once or hundreds of thousands of times.

PERMACHON CAMERA STORAGE TUBE

The Permachon Camera Storage Tube,[1,2] upon which this contract is based, is a light-in, electrical-out tube that provides multicopy readout of an image for long periods of time after the input illumination has been removed. The Permachon camera storage tube is also capable of integrating low-light-level inputs to provide enhancement in video presentations.

Figure 1. Permachon Type Scan-Converter

The physical appearance of the Permachon camera storage tube, as shown in Figure 2, is identical to the six-inch-long by one-inch-diameter magnetic broadcast vidicons. The tube can be operated in standard vidicon cameras and generates grey scales comparable to those of conventional pick-up tubes. These novel operating characteristics are results of the photoconductor materials used.

In a standard broadcast-type vidicon, the photoconductor, a semiconductor material such an antimony trisulfide,[3] is deposited upon a transparent conductive lamina on the inside of the tube's faceplate.

When the electron beam initially scans the photoconductor, it deposits electrons until the back surface of the photoconductor is charged down to the cathode potential. Then, depending on the amount of incident light radiation, the resistivity of the semiconductor decreases, and negative charges move from the back surface of the photoconductor to the conductive lamina (signal electrode), which is normally 5 to 40 volts positive with respect to the cathode. Thus, the illuminated areas rise above cathode potential, and the electron beam, upon rescanning, deposits electrons in these positive areas. This landing of electrons generates the signal current.

The operation of the Permachon camera storage tube is similar to that of the conventional vidicon, except that the image continues to be generated after the input light is removed for periods up to an hour, so

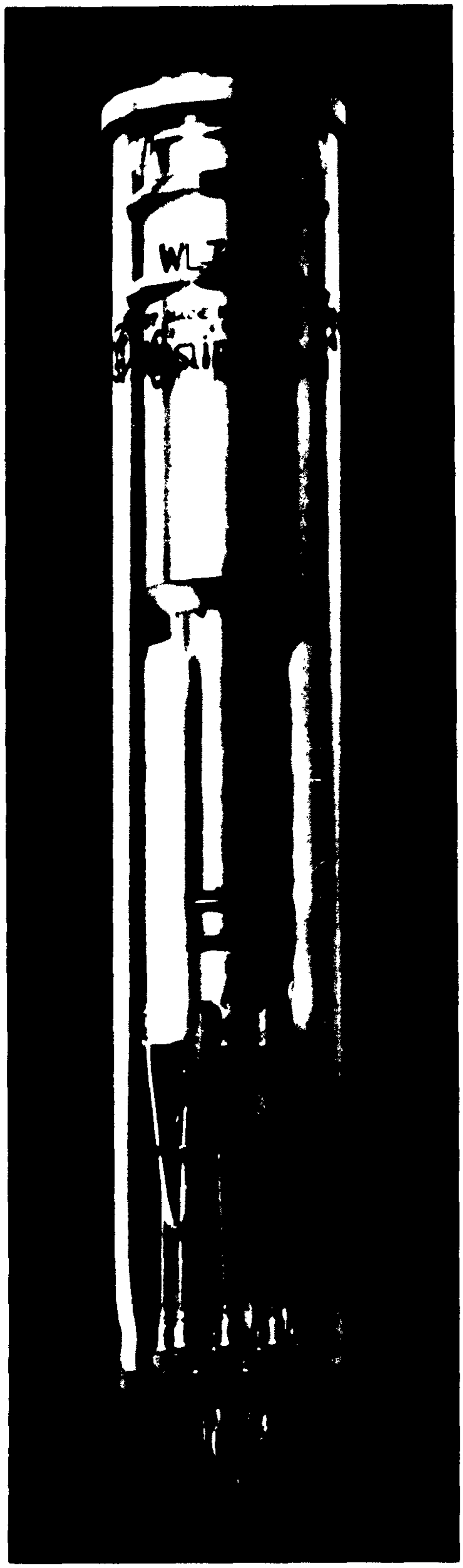


Figure 2. Permachon Camera Storage Tube WL 7383

long as the photoconductor continues to be scanned by the electron beam. The storage duration is a function of target voltage and photoconductor material.

Erasure of the Permachon camera storage tube can be accomplished in two ways:

1. Enhanced erasure. Using this method, the face of the tube is flooded uniformly with light. This process may be carried out in less than a second with about 20 foot-candles or with a single intense flash of approximately 5×10^{-4} seconds in This method requires a priming cycle of five frames of normal TV scanning before the next exposure to visual information. The most complete enhanced erasure is obtained when the electron beam is blanked off during the light pulse.
2. Unenhanced erasure. The stored information may also be erased by just switching off the reading beam. This method requires 5 to 10 seconds for good erasure.

The photoconductor (W #6) that provides these remarkable characteristics is a homogeneous lamina of arsenic and selenium backed by a lamina of antimony trisulfide. This Permachon surface has a wide variety of applications in the storage and imaging field, which are abetted by the fact that the material responds not only to light but also to an electron beam. Thus, a research and development program was undertaken to build a scan-conversion storage tube based upon the Permachon camera storage tube.

TARGET DEVELOPMENT

Two basic types of scan-conversion targets based upon the Permachon camera storage tube were investigated in the execution of this contract: one based on

Electron Bombardment Induced Conductivity (EBIC);

the other based on

Fiber-Optic Photon Transfer (FOPT).

Principles of Operation

The cross sections of two types of EBIC targets are shown in Figures 3 and 4. Both of these targets operate in the same manner, but they differ in that one is supported by aluminum oxide while the other is not.

When the electron beam from the write-gun, which is normally accelerated by 5 kilovolts, bombards an EBIC target, the target undergoes an increase in conduction by an amount that is a function of the signal fed to the write-gun control grid. This action, in combination with the low-velocity electron beam from the reading gun, results in a signal current through the target. The magnitude of this current depends on the voltage across the target material (normally 5 to 20 volts), the energy of the incident electrons, the temperature of the target material, and the composition of the target material.

Permachon photoconductors act as EBIConductors under electron

Al_2O_3 Supported
EBIC Target

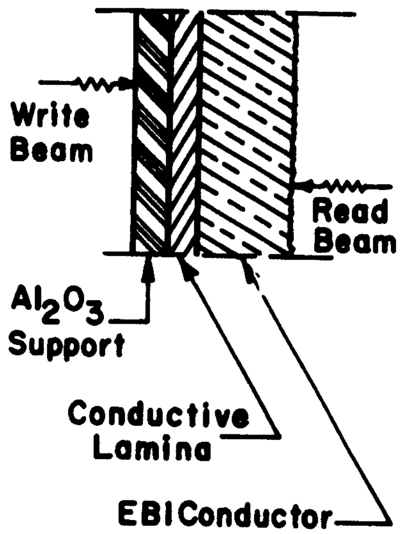


FIGURE 3

Aluminum Supported
EBIC Target

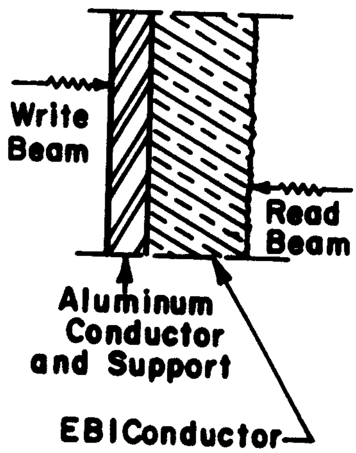


FIGURE 4

(Not to Scale)

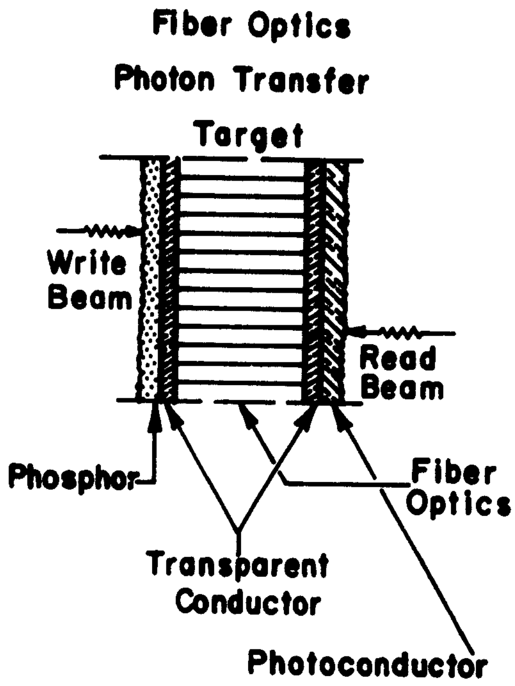
SCAN-CONVERTER TARGETS

bombardment, and as the scan-converter read-gun scans such a target, it deposits electrons and charges the Permachon surface down to the potential of the read-gun cathode while the conductor is at positive voltage. Then, as the write-gun electron beam penetrates the target, the conduction of the EBIC material increases, and the negative charges move from the surface to the backplate of the target, which is positive with respect to the read-gun cathode. Each elemental area is subsequently recharged when scanned by the beam of the read-gun. This charging current flows through the target and load resistor from which the video signal is derived.

Conduction is induced primarily through energy expended by the writing electrons to raise electrons from the valence band of the EBIConductor into the conduction band. Since the number of conduction electrons can be several orders of magnitude higher than the number of high energy electrons triggering conduction, corresponding gains in charge can be realized.

As a result of the current gain, the input writing current is only a small fraction of the total current, and, thus, is undetectable in the output signal. It is this fact that makes the EBIC target suitable for scan-conversion use, since further signal separation is not required.

A cross section of the FOPT target is shown in Figure 5. When the electron beam from the writing gun strikes the phosphor deposited on one side of the fiber-optics target, photons are emitted and transferred via



(Not to Scale)

SCAN - CONVERTER TARGET

FIGURE 5

the fiber-optics to the Permachon photoconductor. The photoconductor is subsequently read-out with a low-velocity electron beam in the same manner as in a Permachon.

Since the input and output currents travel in completely isolated paths, and light acts as the coupling mechanism, this type of target is also useful in scan-conversion tubes.

Target Construction

In the early months of the development program, targets were badly damaged from heat generated during the sealing and exhaust phases of tube fabrication. Photoconductors are very susceptible to damage at temperatures greater than 50°C, because above this point they outgas in the vacuum of the tube, crystallize, and change composition. One or more of these occurrences will lower the resistivity of the photoconductor, causing a rise in dark current, which is detrimental to storage. This problem was avoided in the final phases of the contract by a change in the method and sequence of assembling the tube.

FOPT Target

To fabricate a FOPT target, a one-inch-diameter by one-tenth-inch-thick fiber-optics plate is scrupulously cleaned, after it is received in a polished condition from the manufacturer, Mosaic Fabrications, Inc. Then, transparent conductive laminae are evaporated or sprayed upon both sides; various materials, including aluminum, gold, and stannic oxide, have been used. The aluminum was found to be too opaque at the required resistances, and the gold did not adhere well after it was evaporated, making it almost impossible to ensure electrical contact. The stannic-oxide coatings have the disadvantages of requiring application at temperatures of about 500°C and having wide variations in the resulting resistances. The stannic-oxide has the advantages of durability, adherence, and good light transmission of better than 90%. The majority of fiber-optics targets used had this type of conductor, and, should further scan-converter development be performed, modified techniques for depositing this material will be investigated.

After the conductive laminae are deposited on the fiber-optics plate, it is coated on one side with a phosphor, preferably P-20, which best matches the spectral sensitivity of the Permachon photoconductor. During the first portion of the contract, settled phosphors were used, and later, catophoretic deposition was tried to obtain smaller particle size.

Once the phosphor is dried, the reverse side of the fiber-optics plate is coated with the Permachon photoconductor. Several different types of photoconductors were used during the contract, but the one which best duplicated the performance of a Permachon vidicon was a lamina of arsenic triselenide backed by a second lamina of antimony trisulfide.

EBIC Target

Two structurally different types of EBIC targets were evaluated.

These targets were all 3/4 inch in diameter, and one was supported by an aluminum-oxide substrate 500 to 1000Å thick, while the other was supported directly by aluminum either edge-supported or mesh-supported. These targets, being extremely thin and fragile, were subject to breakage from expansion and contraction, reaction with the EBIConductor, pressure differentials during exhaust, and mechanical acceleration. This, needless to say, made it quite difficult to fabricate and test such a target. When the mesh-supported target was developed, breakage of the aluminum target was eliminated.

The aluminum-supported EBIC targets are constructed by first placing a thin layer of lacquer on the target ring. The lacquer is then coated with evaporated aluminum, and the lacquer is removed, leaving the edge-supported aluminum film. The EBIConductor is then evaporated onto the aluminum film. A mesh-supported target is formed in much the same manner, except that a fine wire mesh is stretched across and fastened to the target ring before it is lacquered.

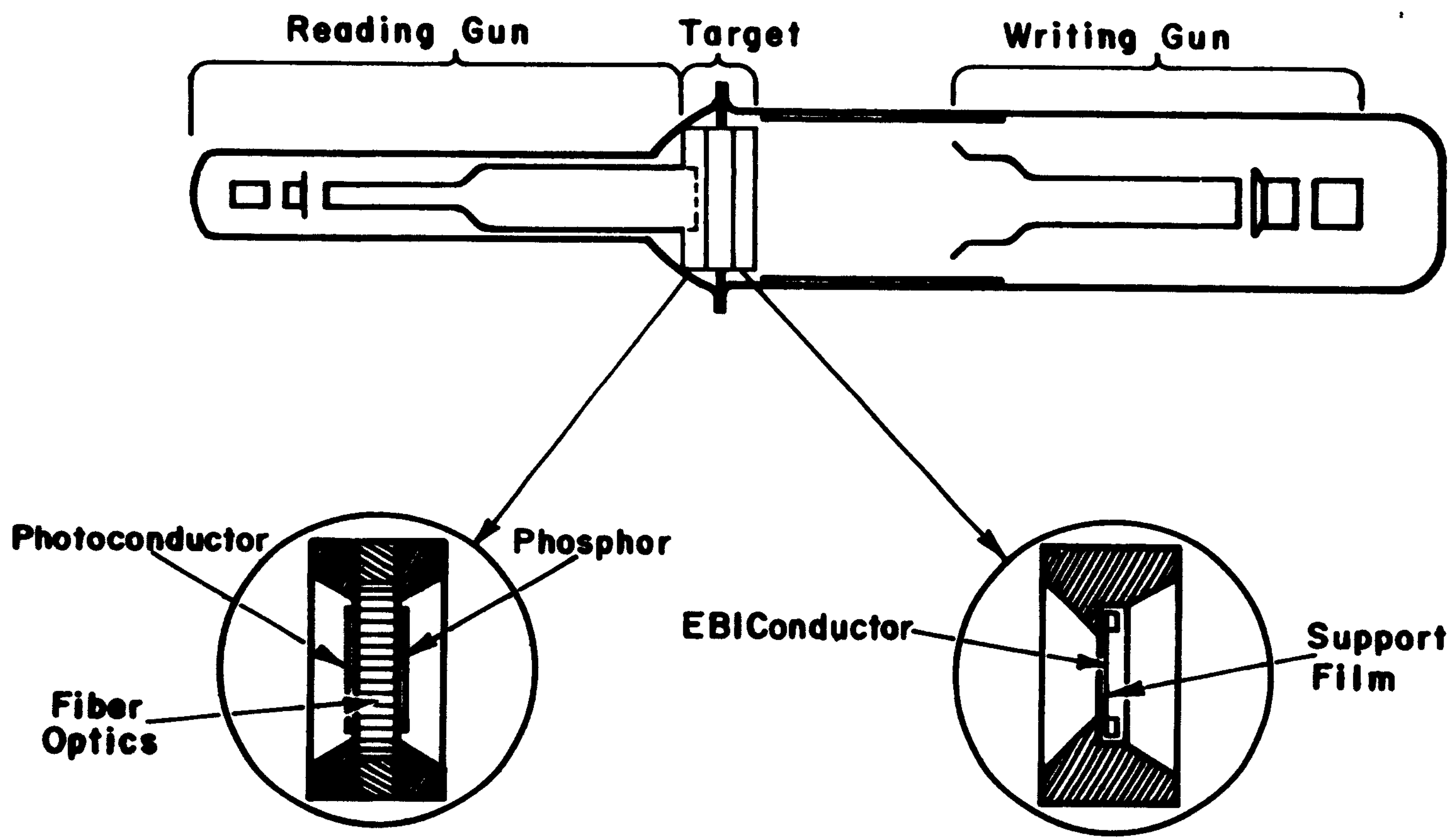
To fabricate the aluminum-oxide-supported target, a piece of aluminum foil is anodized to form an aluminum-oxide coating over its entire surface. Subsequently, the aluminum oxide is removed from one side of the foil with sodium hydroxide, leaving a layer of aluminum coated on one side with aluminum oxide. The remaining aluminum is then removed with hydrochloric acid, leaving just the aluminum oxide.

This aluminum-oxide sheet is mounted on a target ring and coated with a conductor, such as aluminum, to form the target backplate or signal electrode. The Permachon material is then deposited on the conductor to complete the target.

STRUCTURE DEVELOPMENT

Six envelope designs and target-mounting structures were evaluated for both the EBIC and FOPT targets; the last of these designs is shown in Figure 6, with enlarged views of the FOPT and EBIC target mounts. Detailed drawings of the mounts were shown in Quarterly Reports 8 and 9.

Figure 7 is a cross section drawing of the most recent envelope design, which is made from 7052 glass tubing. This tube is aluminized, as shown in Figure 8, to provide the anode for the writing gun. After aluminizing, the reading electron gun is sealed into the smaller diameter end of the bulb to form the assembly shown in Figure 9. The target assembly whether it is EBIC or FOPT, is now inserted into the bulb as shown in Figure 10 (a photograph taken in the main clean room of the Image Tube Technology Laboratory). This picture shows a technician inserting a target held atop an adjustable target-inserting fixture. When the target assembly is in place with respect to the bulb eyelets, holding pins are inserted into the ceramic target mount to hold it in place. The tube is now moved to the welding room of the laboratory, where the pins are heliarc welded in place, using the setup and the special heat-sink grounding fixture



FIBER OPTICS TARGET

EBIC TARGET

SCAN CONVERTER CROSS-SECTION

FIGURE 6

1. 1.445 O.D. Bulb
2. 1.020 O.D. Bulb
3. Eyelet (Kovar)

All dimensions in inches

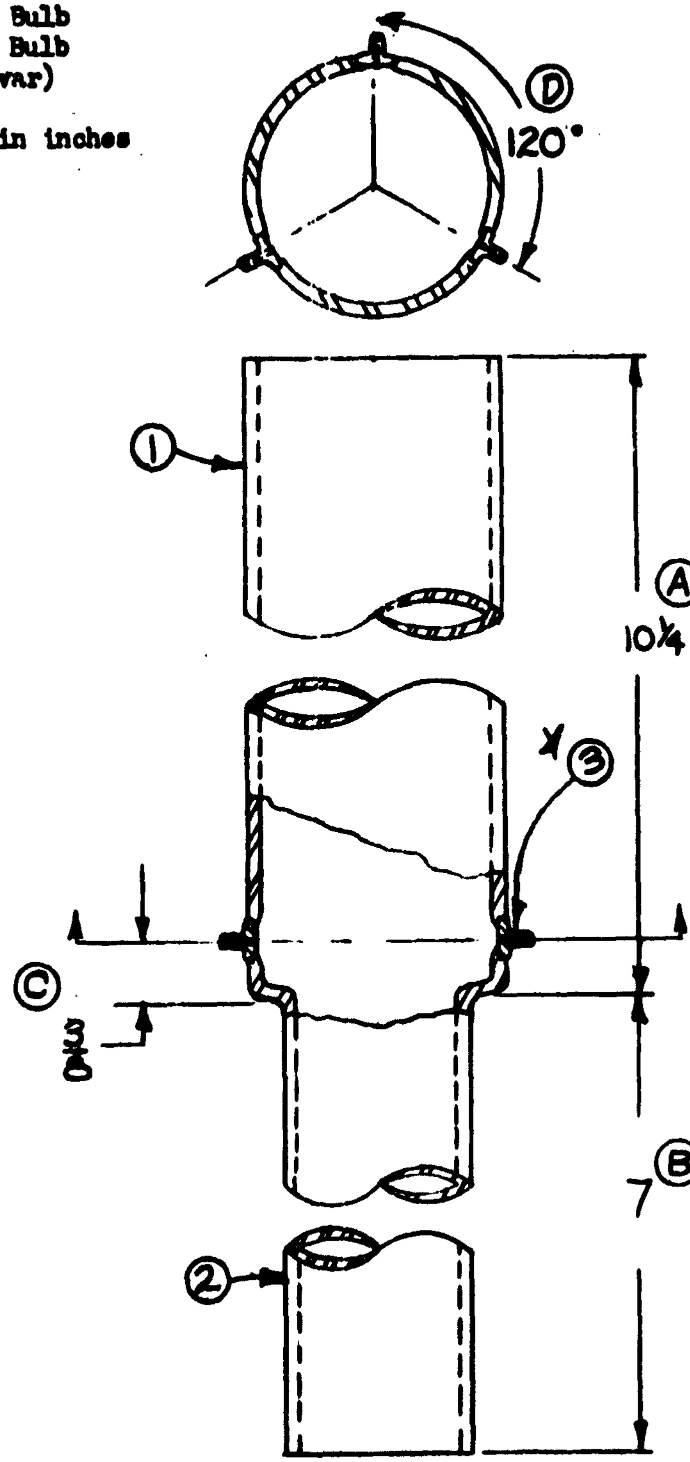


Figure 7. Tube Envelope

1. Tube Envelope
2. Aluminum Coating

All dimensions in inches

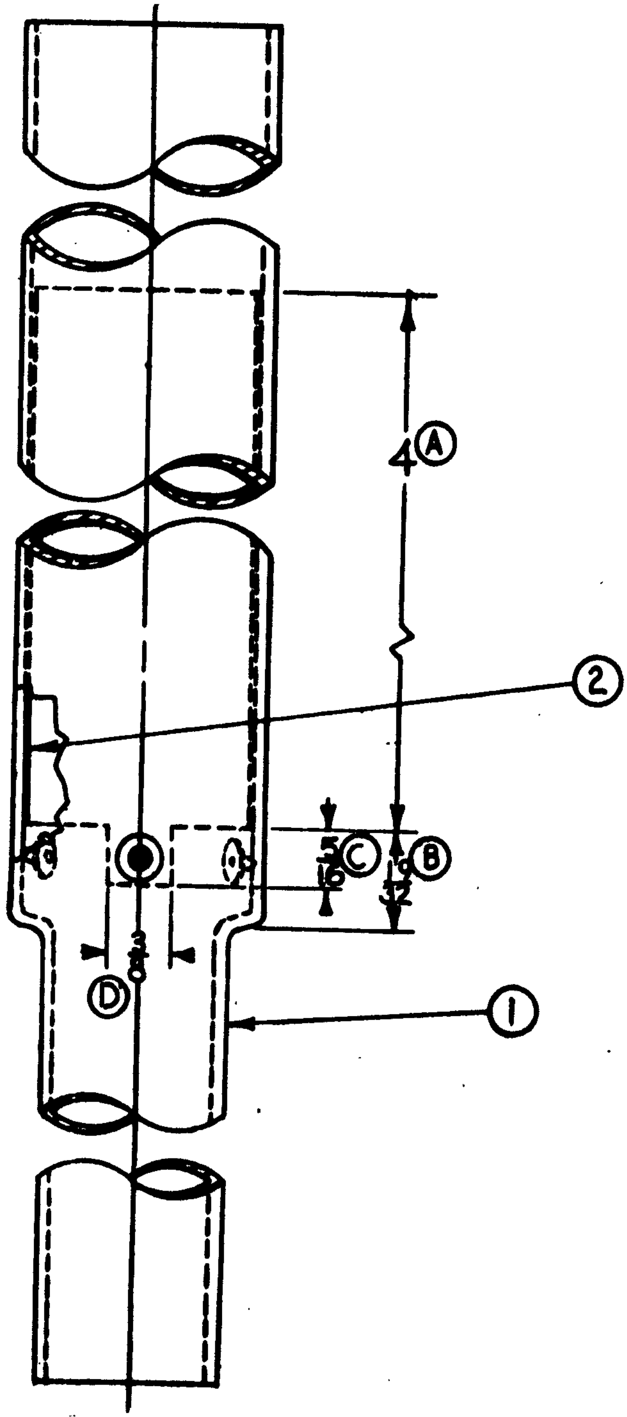


Figure 8. Aluminized Envelope

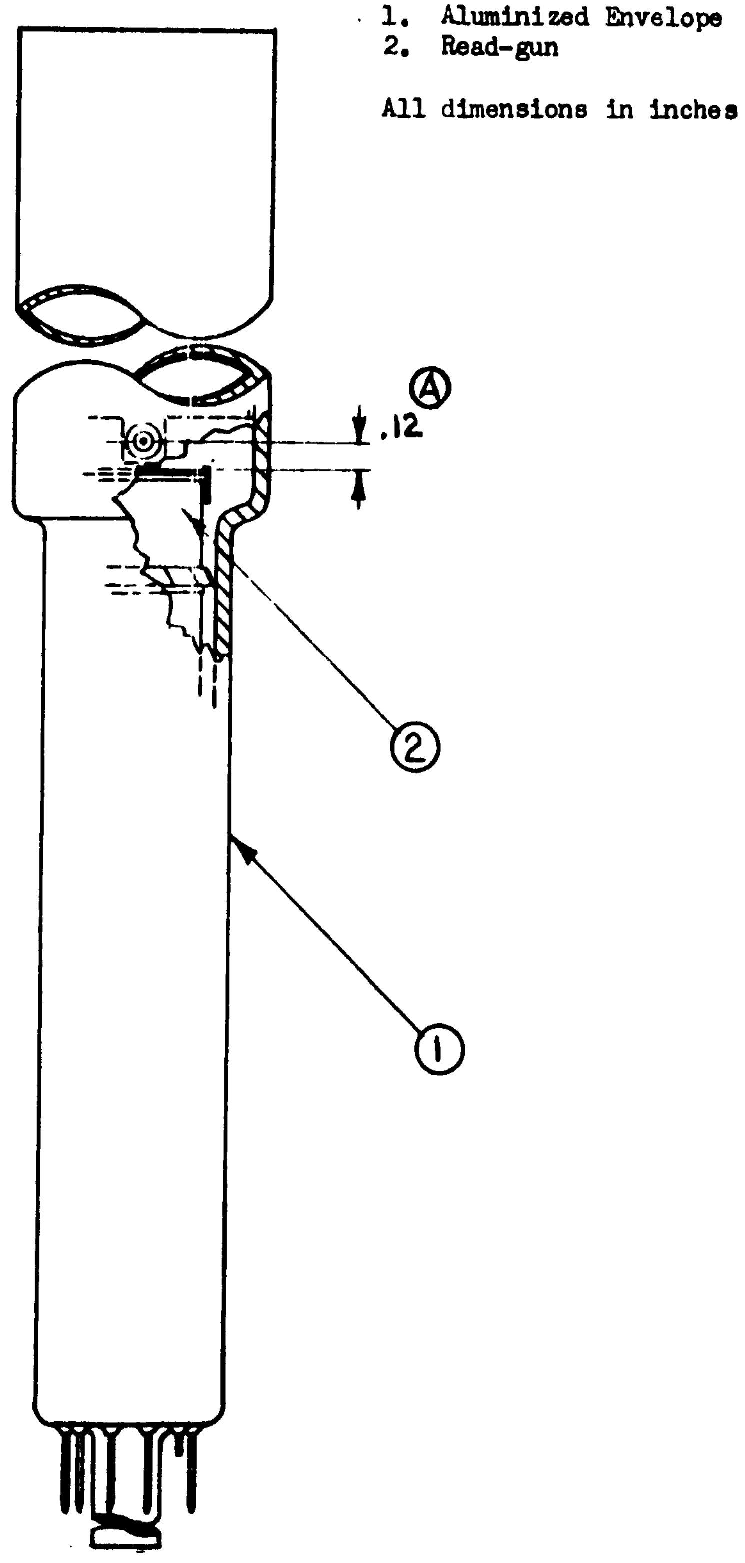


Figure 9. Envelope with Read-Gun

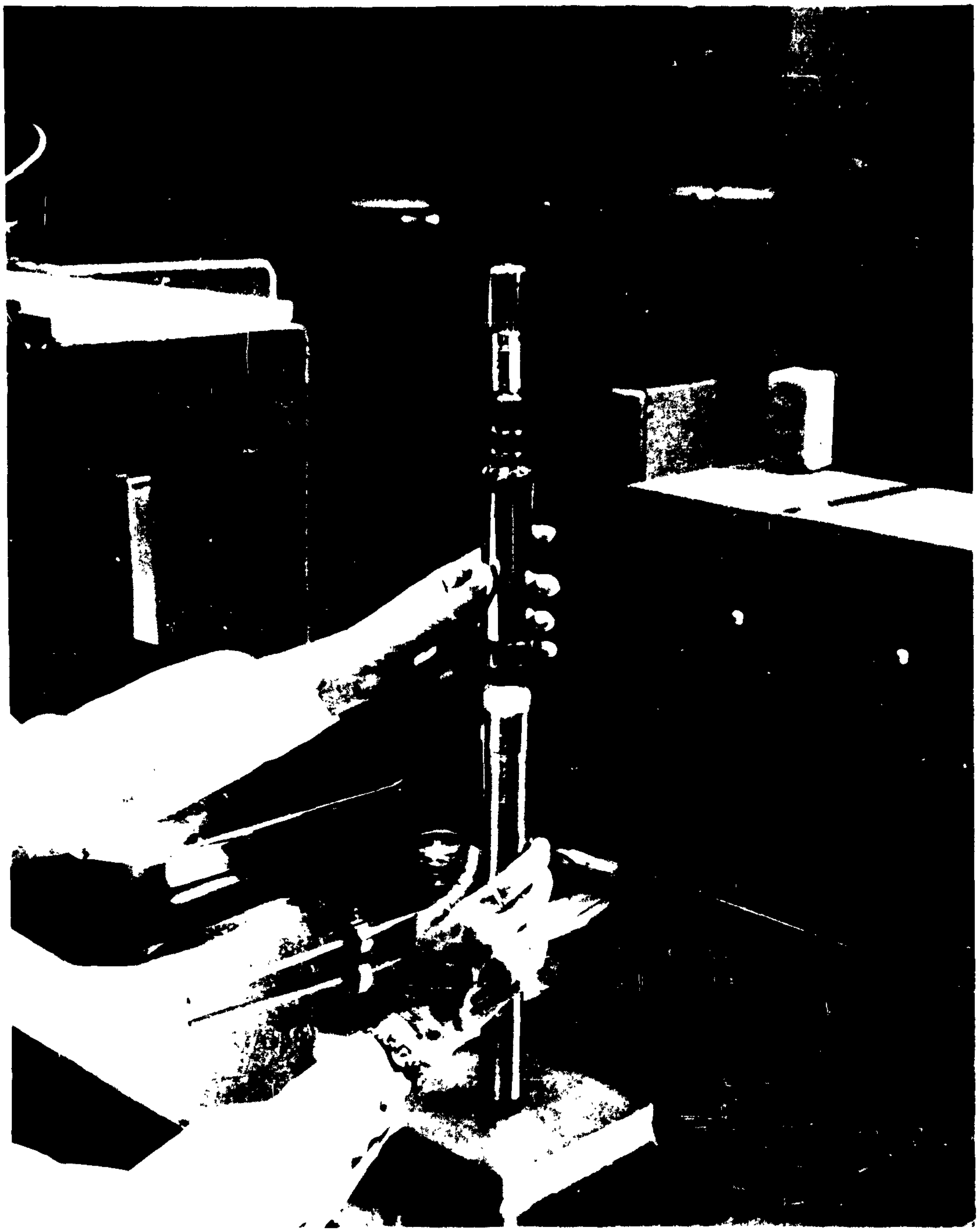


Figure 1[illegible]. The Insertion of the Thr[illegible] shown in Figure 11. Figure 12 is a drawing of the subassembly, which is completed with the welding operation. To complete the tube as shown in Figure 13, the write-gun is sealed on a horizontal glass-sealing lathe. This assembly is sealed onto the vacuum system as shown in Figure 14, where it is exhausted and the cathodes are processed.

ELECTRON OPTICS

Writing Gun

The writing gun used in almost all of the scan-conversion tubes is an electrostatically-focused and magnetically-deflected gun adapted from the Westinghouse 5 CEP11 cathode-ray tube (see Figure 15). When the gun is operated at 10 kilovolts acceleration with 10 microamperes of beam current at a 30-mircosecond-per-inch scanning rate, the line-width is 0.0015 inch, measured at the half-amplitude point of the light energy distribution from a P-11 phosphor. Therefore, with the 3/4-inch-diameter target in the scan-converter it is theoretically possible to generate 500 black and white lines at 50% response factor. In several of the most recent tubes with FOPT targets the maximum resolution measured was 350 black and white lines. This resolution limitation is due in part to the lower acceleration potential used, 5 kilovolts, the light diffusion introduced by the transparent conductive laminae on both sides of the fiber-optics, and the edge-splitting caused by individual glass fibers.

Reading Gun

The reading electron gun used in the scan-converter is shown

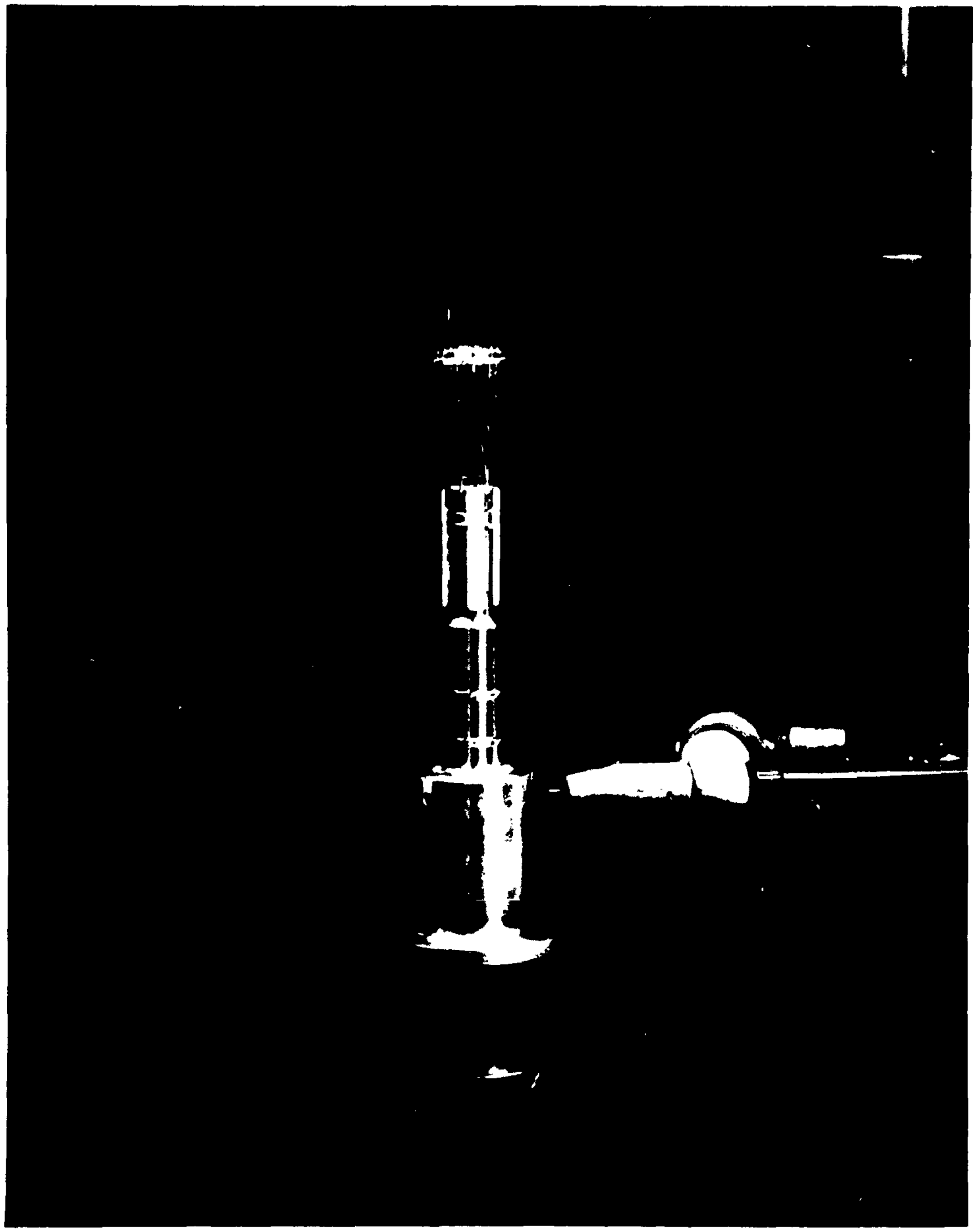


Figure 11. Setup for Heliarc-Welding the Welding Pins

1. Envelope with Read-gun
2. Target Assembly
3. Holding Pin

All dimensions in inches

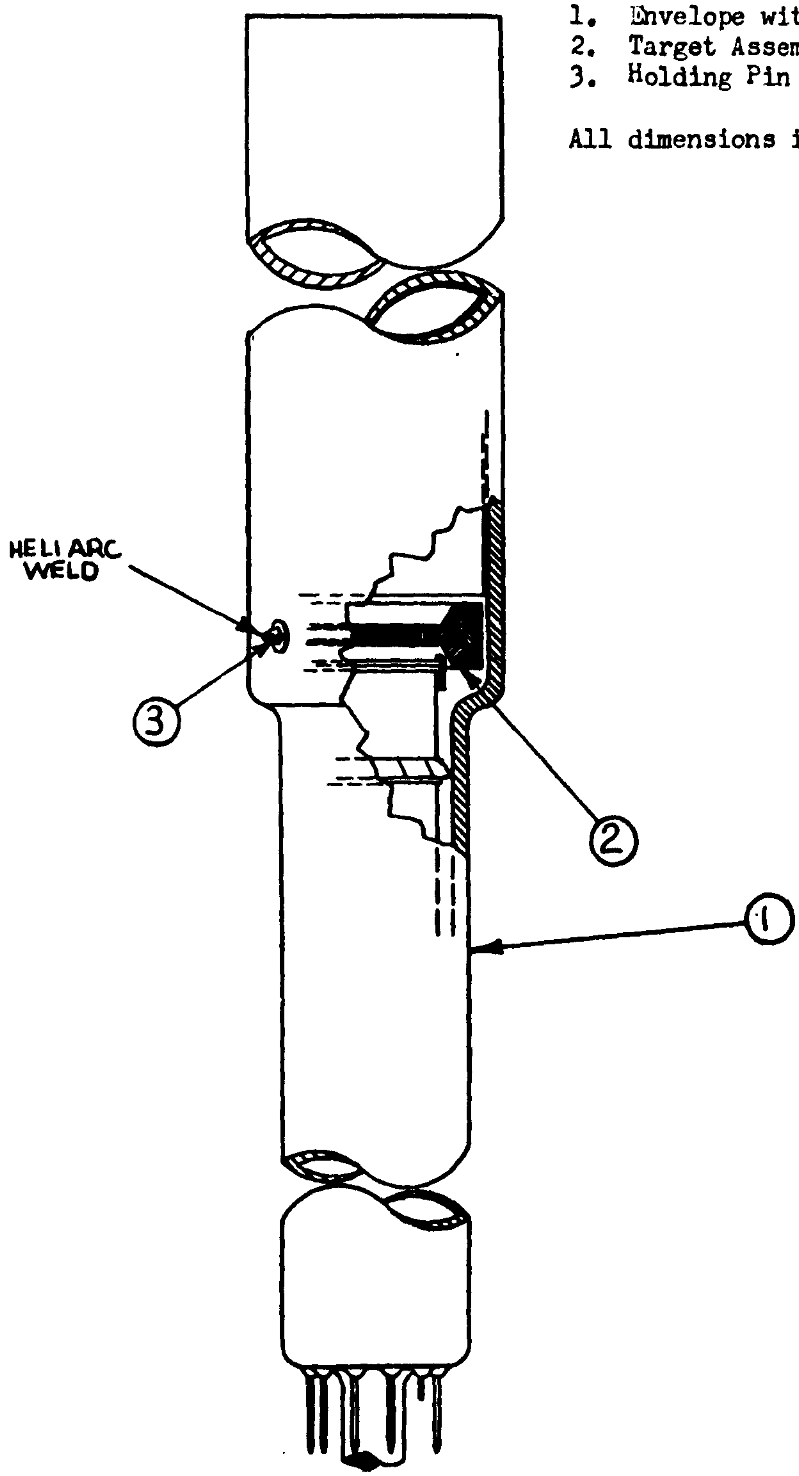


Figure 12. Envelope with Read-Gun and Target

1. Envelope with Read and Target
2. Write gun

All dimensions in inch

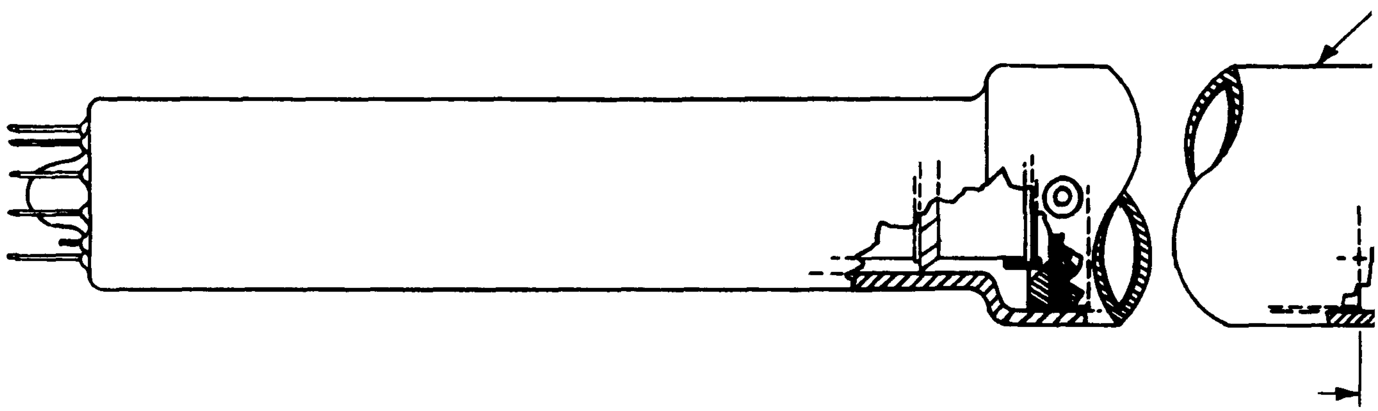
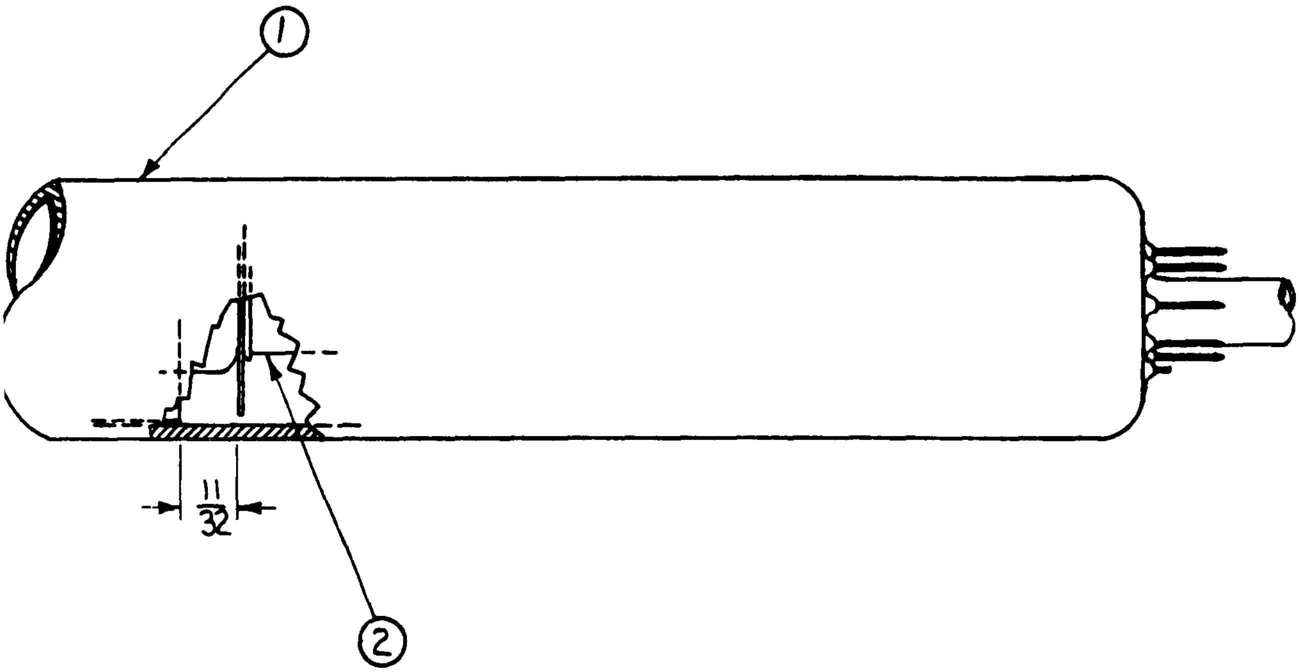


Figure 13. The Tube Assembly Prior to I

.ope with Read-gun
'arget
· gun

sions in inches



›ly Prior to Exhaust

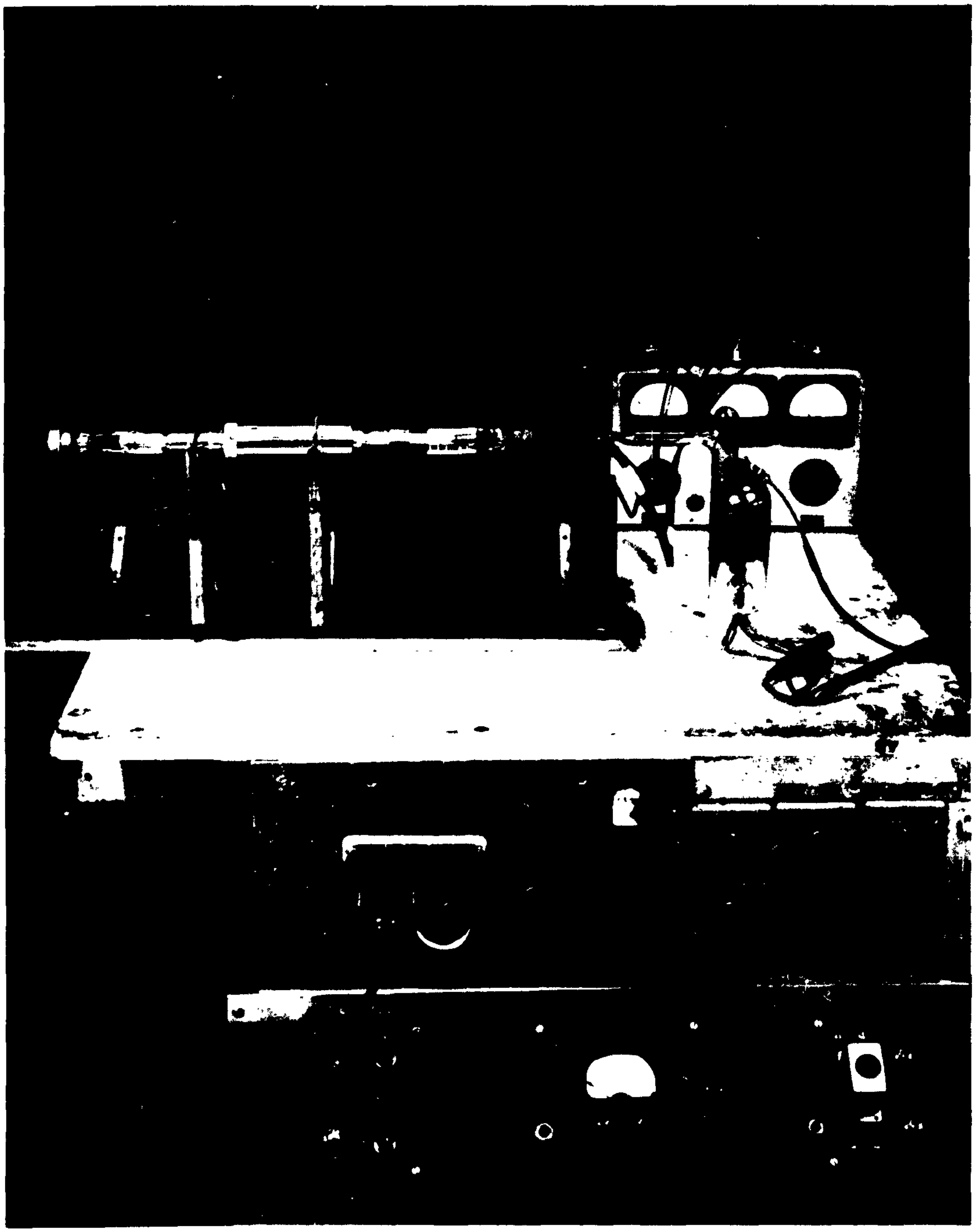


Figure 14. The Tube Sealed on the Vacuum System

1. Gun Assembly
2. Stem
3. Getter

All dimensions in inches

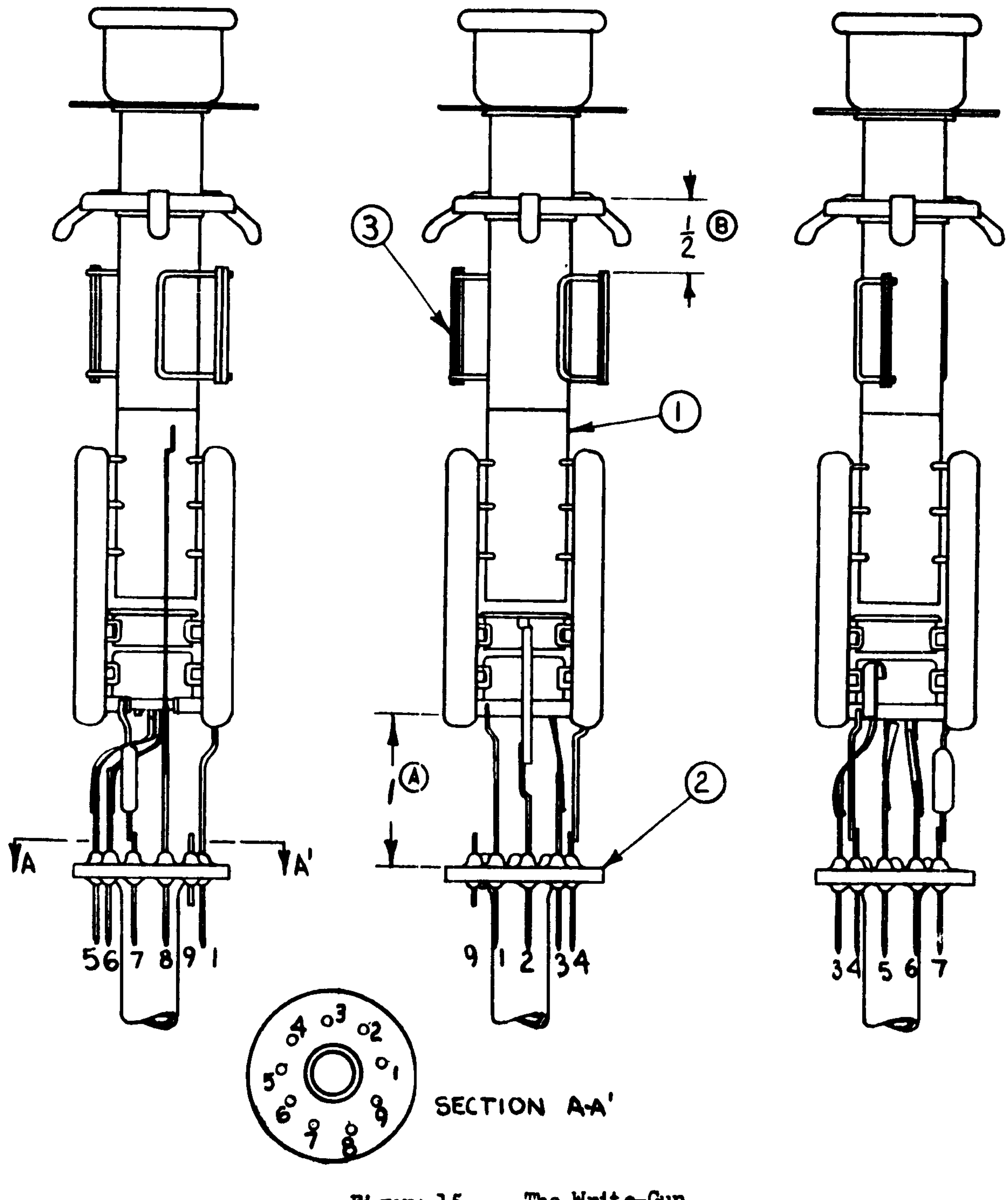


Figure 15. The Write-Gun

in Figure 16. This gun is very similar to the one used in the Westinghouse Permachon camera storage tube WL 7383. In this tube, the gun is capable of resolving 600 TV lines per 3/8 inch.

TUBES CONSTRUCTED

A total of one hundred scan-conversion tubes were built during this contract, as well as other special vidicons and cathode-ray tubes. Table I indicates the number and types of tubes constructed during each quarterly period. Details of the specific tubes from 1 to 93 are contained in the Quarterly Reports, and tubes 94 through 100 are listed in Table II of this report.

All the scan-conversion tubes made during this last quarterly period contained FOPT targets and electromagnetic read- and write-guns.

TEST EQUIPMENT

Figure 17 is a photograph of the test set used to test and evaluate experimental scan-conversion tubes. Most of this equipment was designed, developed, and constructed by Westinghouse and is comprised of the basic power supplies, drive circuitry, and monitors required to operate the scan-converter tube, as well as special signal sources and control apparatus.

A scan-converter tube under test is held in a horizontal position in the center portion of the equipment, where the focusing and deflecting

1. Stem
2. Gun Assembly
3. Mesh Support
4. Mesh Assembly
5. Getter
6. Cross Support
7. G_1 Connector
8. Support
9. G_2 Con
10. G_2 Lea
11. G_3 Lea
12. Connec
13. Grid S

All dimensions in inches

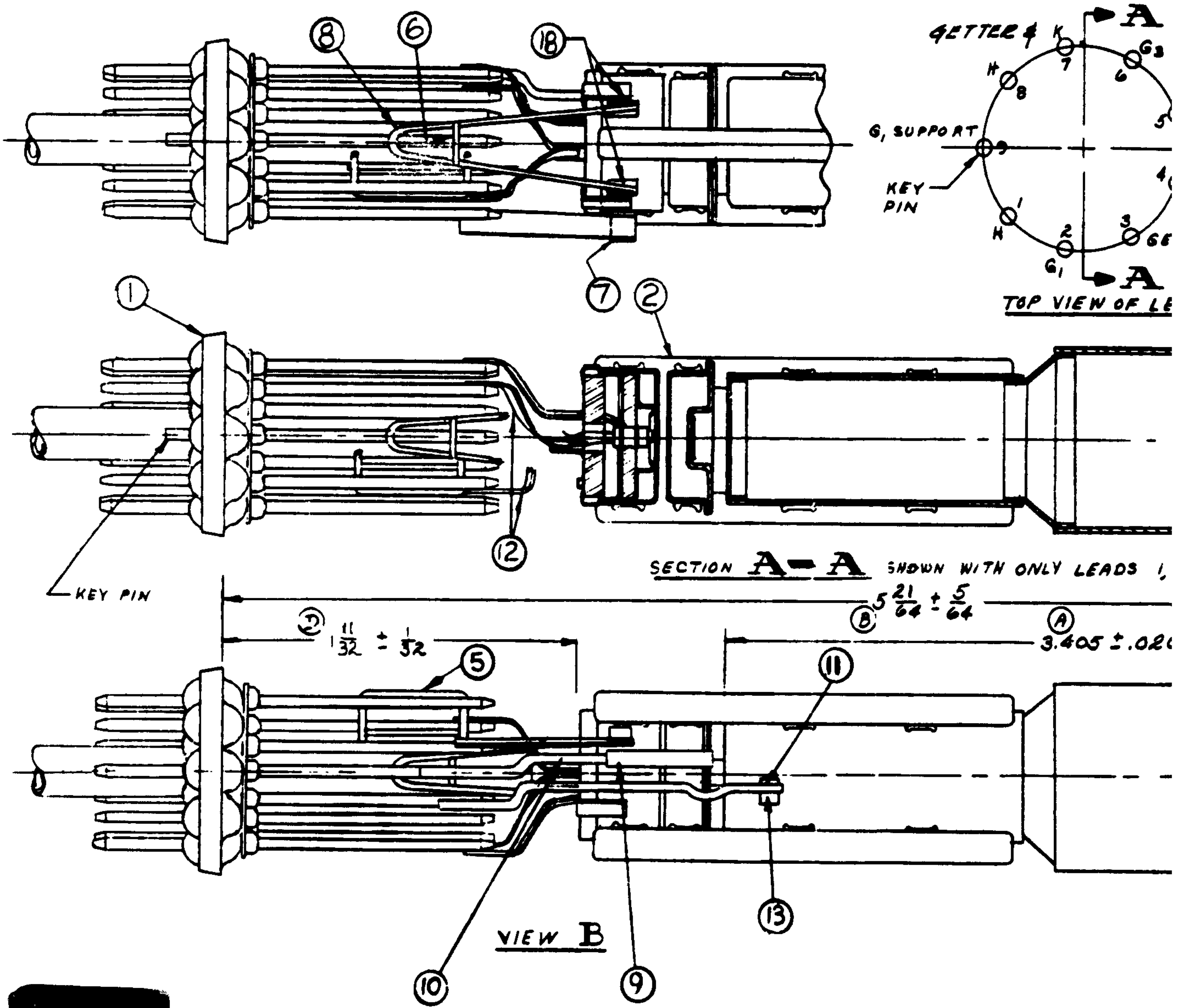
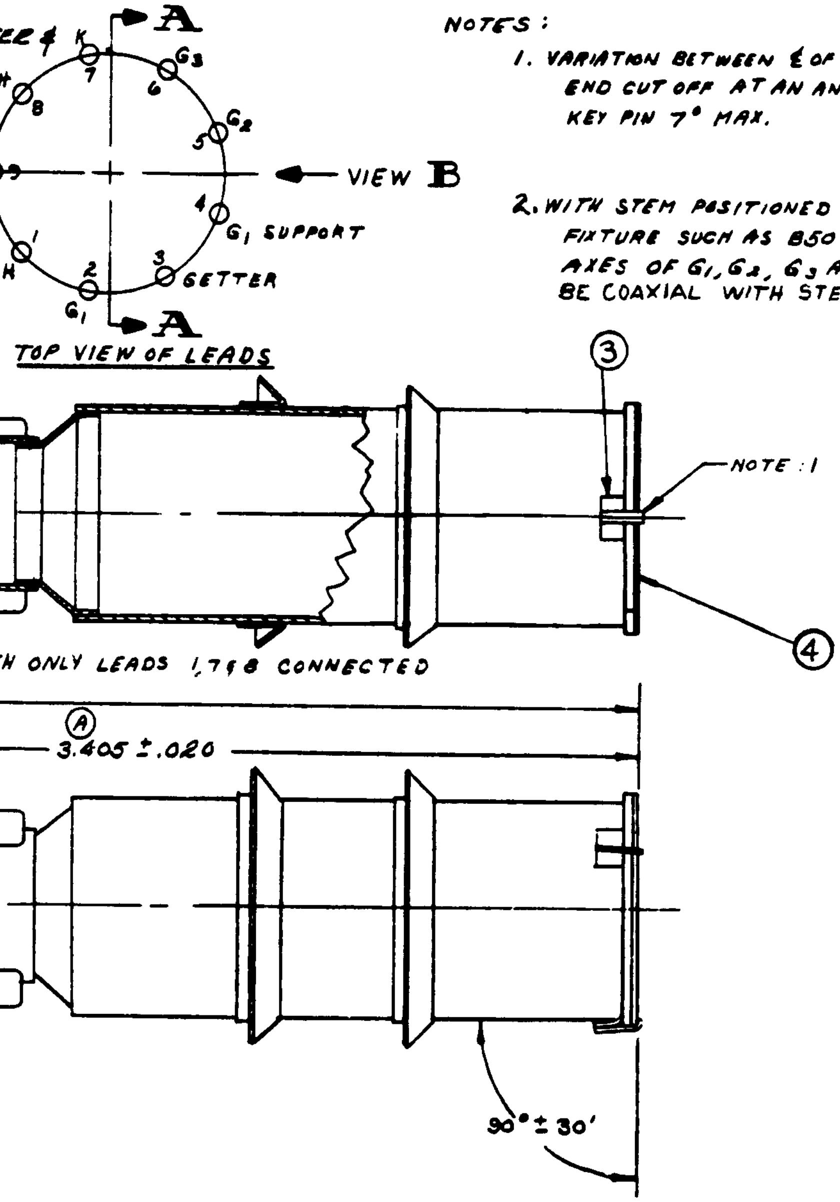


Figure 16. The Read-Gun

ort
or

9. G_2 Connector
10. G_2 Lead
11. G_3 Lead
12. Connector
13. Grid Support



NOTES:

1. VARIATION BETWEEN ℄ OF MESH TAB WITH END CUT OFF AT AN ANGLE AND ℄ OF KEY PIN 7° MAX.

2. WITH STEM POSITIONED BY PINS IN A FIXTURE SUCH AS B50-67T2 ITEM 4, AXES OF G_1, G_2, G_3 ASSEMBLIES TO BE COAXIAL WITH STEM WITHIN .005

ad–Gun

TABLE I

SCAN-CONVERTER TUBES CONSTRUCTED

Quarterly Period	Target Types				Tubes per Quarter
	Aluminum Oxide	Aluminum (self-supported)	Aluminum (mesh-supported)	Fiber-Optics	
1	-	-	-	7	7
2	-	-	-	2	2
3	-	6	-	10	16
4	-	9	-	-	9
5	1	-	-	-	1
6	14	1	-	-	15
7	14	9	-	-	23
8	10	-	2	3	15
9	-	-	2	3	5
10	-	-	-	7	7
Totals	39	25	4	32	100 Grand Total

TABLE II

SCAN-CONVERTERS MADE DURING THE 10TH QUARTER

Tube No.	Seal-in Date	Photoconductor Material	Operational or Characteristics	Reason for Failure
94	10/3/62	W#6	Target removed and put into #95	Poor emission, read-gun
95	10/15/62	W#6	Good storage and erasure	
96	10/31/62	W#6		Lost contact with gold under photoconductor
97	11/8/62	W#6	Good operation Like a Permachon	
98	11/26/62	W#6		No contact with gold under photoconductor
99	11/30/62	Sb_2S_3		Resistivity of photo-conductor too low
100	12/26/62	W#6	Target removed and put into #101	Poor emission, read-gun

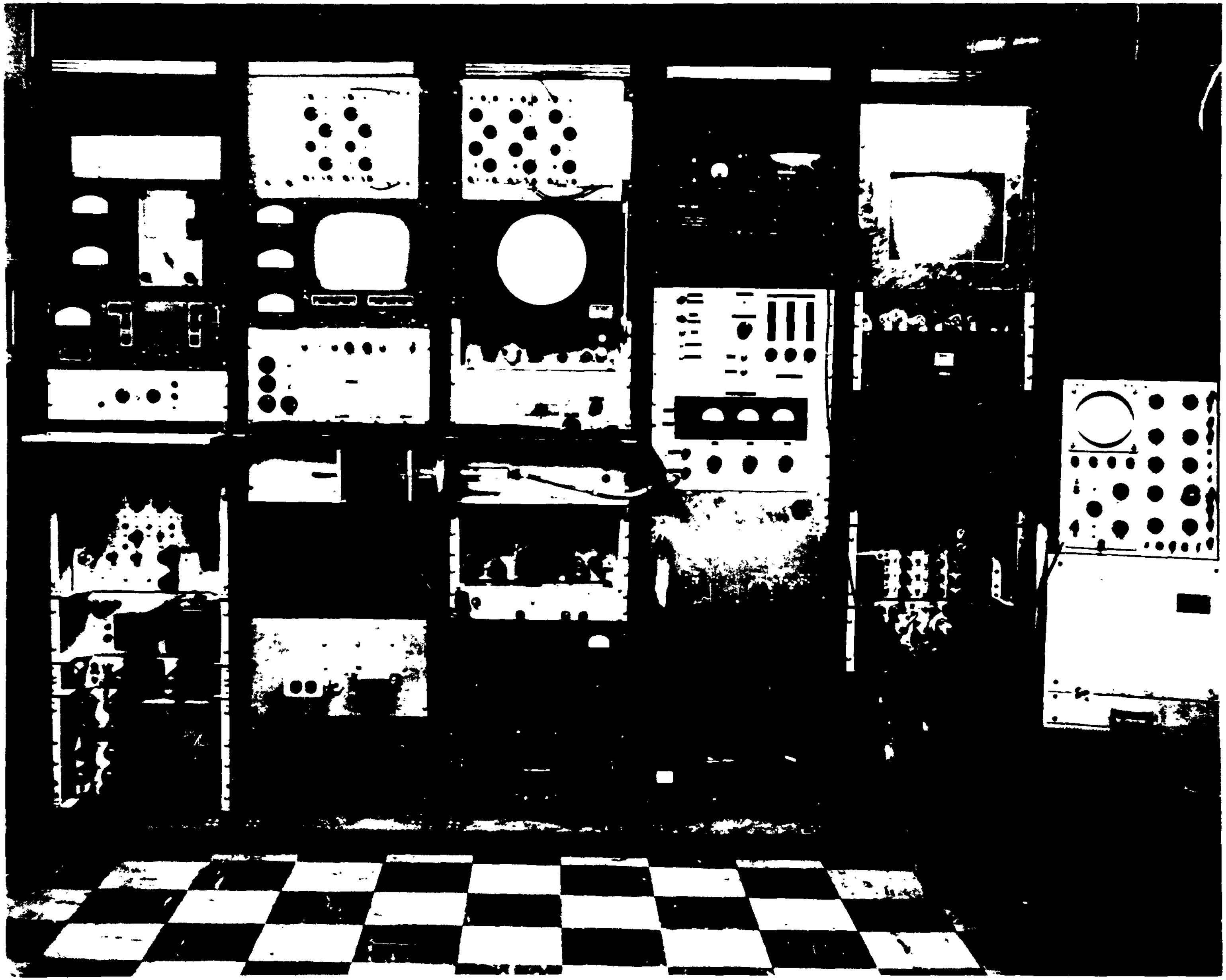


Figure 17. The Scan-Converter Test Equipment

coils for the read-gun and the deflection-yoke of the write-gun are located. The write-gun is electrostatically focused.

A modified vidicon test set incorporated into the left-hand section of the test set supplies the electrode potentials for the read-gun as well as the necessary deflection and focusing currents. The required controls and metering are also located in this section. The scan-converter output signal is fed into a low-noise cascode-input video-amplifier stage and through an eight-megacycle video amplifier to the output monitor.

The write-gun is normally operated with its cathode a five kilovolts negative with respect to the target, which is near ground potential. Therefore, the write-gun electrode potentials are derived from a special power supply, in the right-hand portion of the set, that is floating at the negative potential of the cathode.

Signal Sources

Three basic signal-sources are now available as inputs for the scan-conversion tubes, and these can be selected for the tube by means of a coaxial switch.

Resolved-Time-Base PPI

The PPI time-base and gating waveform are generated from the group of Tektronix signal generators located along the top of the test set. The PPI rotation is controlled by a synchronous motor that drives a resolver at ten revolutions per minute. The circular monitor in the set provides a display of the PPI information being fed to the write-gun, usually consisting of a number of concentric range-rings variable from 10 to 200.

Monoscope

A Telechrome monoscope generator located in the extreme right side of the set generates the standard-type indian head pattern at standard TV scan rates. This signal is monitored on the main fourteen-inch TV display in the center of the set.

Sine Wave

A Foto-Video Model V333A TV and radar keyed-video-signal generator is used to write bar-patterns from 2 to 750 lines into the scan-converter. This input signal is also monitored on the main output display.

Control Equipment

Included in the isolated power supply for the write-gun is a cathode-control circuit that can be triggered either by a manual push-button or by a pulse from the dual-preset frame and field counter to bias the write-gun on or off. This unique control unit can be operated in either one of two modes. In the recycle mode the counter will bias the write-gun on and off continuously for the preset counts, while in the single-short mode it will bias the gun on and off for the preset counts once and then stop.

To operate either mode, the counter is preset for N_1 fields or PPI rotations "on" and N_2 fields or PPI rotations "off"; N being any digit from 1 to 999, and N_1 not equal to N_2. Then the manual start switch is closed and the preset sequence is executed.

All input signals can be gated by this counter, which makes possible the accurate measurement of writing parameters.

Additional equipment is being designed for incorporation in the test set, including drive-circuitry for electrostatic writing and reading, a staircase generator for grey-scale reproduction, and circuitry to utilize the dual preset frame and field counter for control of the read-gun.

TEST RESULTS

Many and varied types of tests were performed during the course of this contract. Specific results on experiments performed during the first nine quarterly periods are included in the Quarterly Reports.

In general, the testing revealed that the aluminum-supported Permachon-type EBIC target provides long storage, and signals were stored for periods of over one hour with no dark-current build-up,* only a very

Note: Dark-current build-up in the storage layer displays itself during read-out of a stored signal as a DC level displacement that raises the average of the video signal away from the base-line, causing shading and a reduction in the contrast of the output signal. Conversely, signal decay occurs during read-out of a stored signal when the peak-to-peak amplitude of the stored signal decreases, causing a reduction in the contrast of the output signal. Dark-durrent build-up and/or signal decay cause degradation in the quality of the output signal.

slow signal decay. In most other types of Permachon targets, dark-current buildup limits the duration of storage. Unfortunately, this target is difficult to erase, making its use in scan-conversion tubes limited.

Aluminum-oxide-supported targets with the Permachon EBIConductor were not found to provide a suitable storage characteristic, but they performed like a laggy photoconductor, which is not characteristic of the Permachon camera storage tube.

The fiber-optics target provides the Permachon photoconductor with a photon input similar to that which triggers it in the vidicon. Tests to date show that this target provides storage characteristics most similar to those of the Permachon camera storage tube.

Tenth Quarterly Period

During the last quarterly period two tubes, numbers 95 and 97, containing FOPT targets with W #6 photoconductors, were evaluated in detail. These tubes had very similar targets, except where noted in the chart below.

Tube No.	Stannic Oxide Under Photoconductor	Stannic Oxide Under Phosphor	Phosphor	Photoconductor
95	300 Ω/sq.	10K Ω/sq.	P-20	W#6
97	2.5K Ω/sq.	50K Ω/sq.	P-20	W#6

In both of these tubes the read-gun filaments operated at 6.3V and 150 mA and the write-gun filaments operated at 6.3V and 600 mA.

Writing

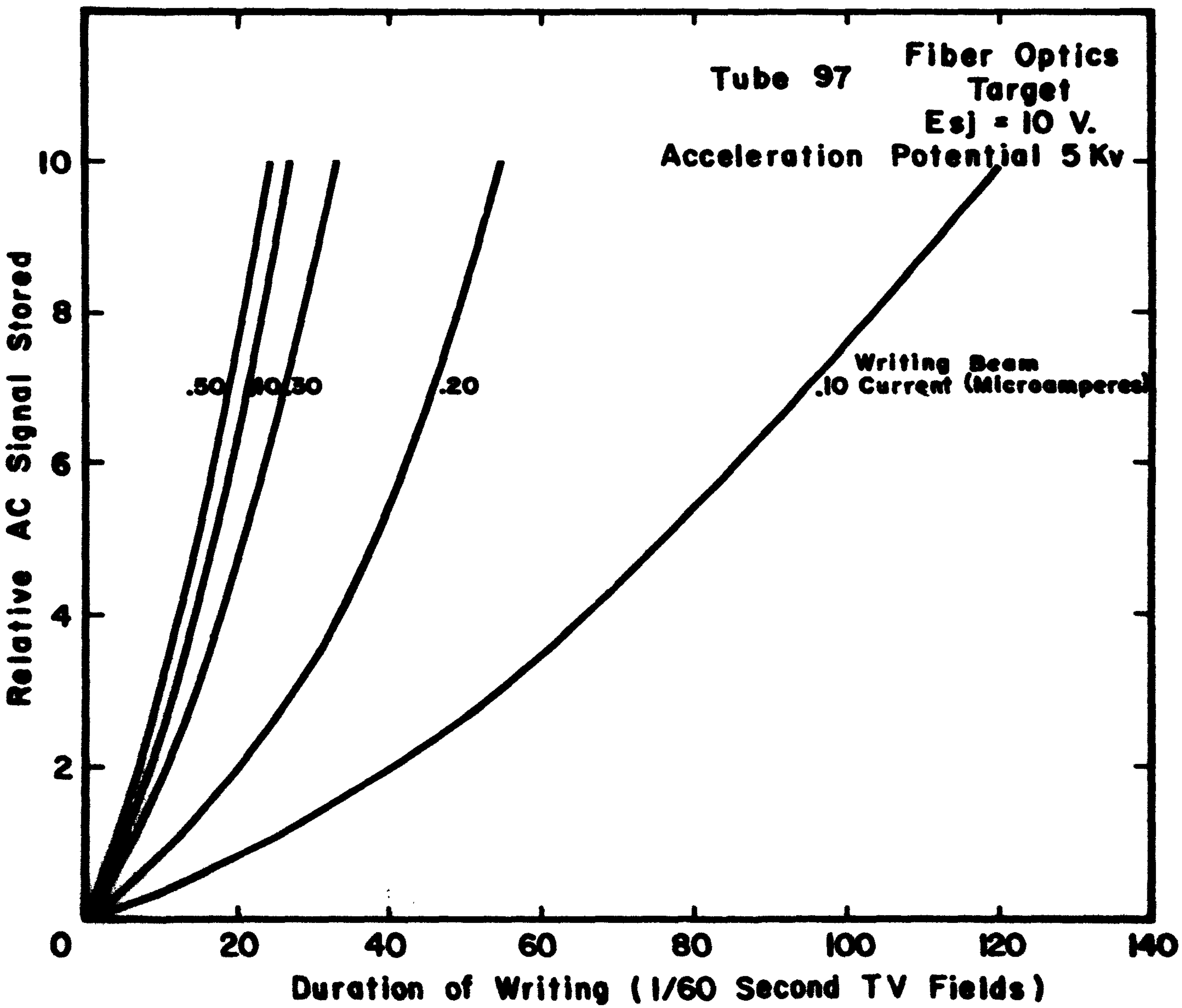
Writing speed is a function of the intensity of light impinging on the photoconductor, which, in turn, is a function of the phosphor material and the energy of the writing electron beam. Figure 18 is a graph of the writing speed of tube 97 at different writing beam currents. The writing speed of tube 95 was very nearly the same.

Although the writing speed increases with increasing beam current (at constant acceleration potential) a point of saturation is reached at about 0.5 microampere, and it is important to note that the resolution begins to diminish long before the saturation point is reached. At this time, it requires about one second to write and store a high-quality image into a tube with a FOPT target.

Storage and Read-Out

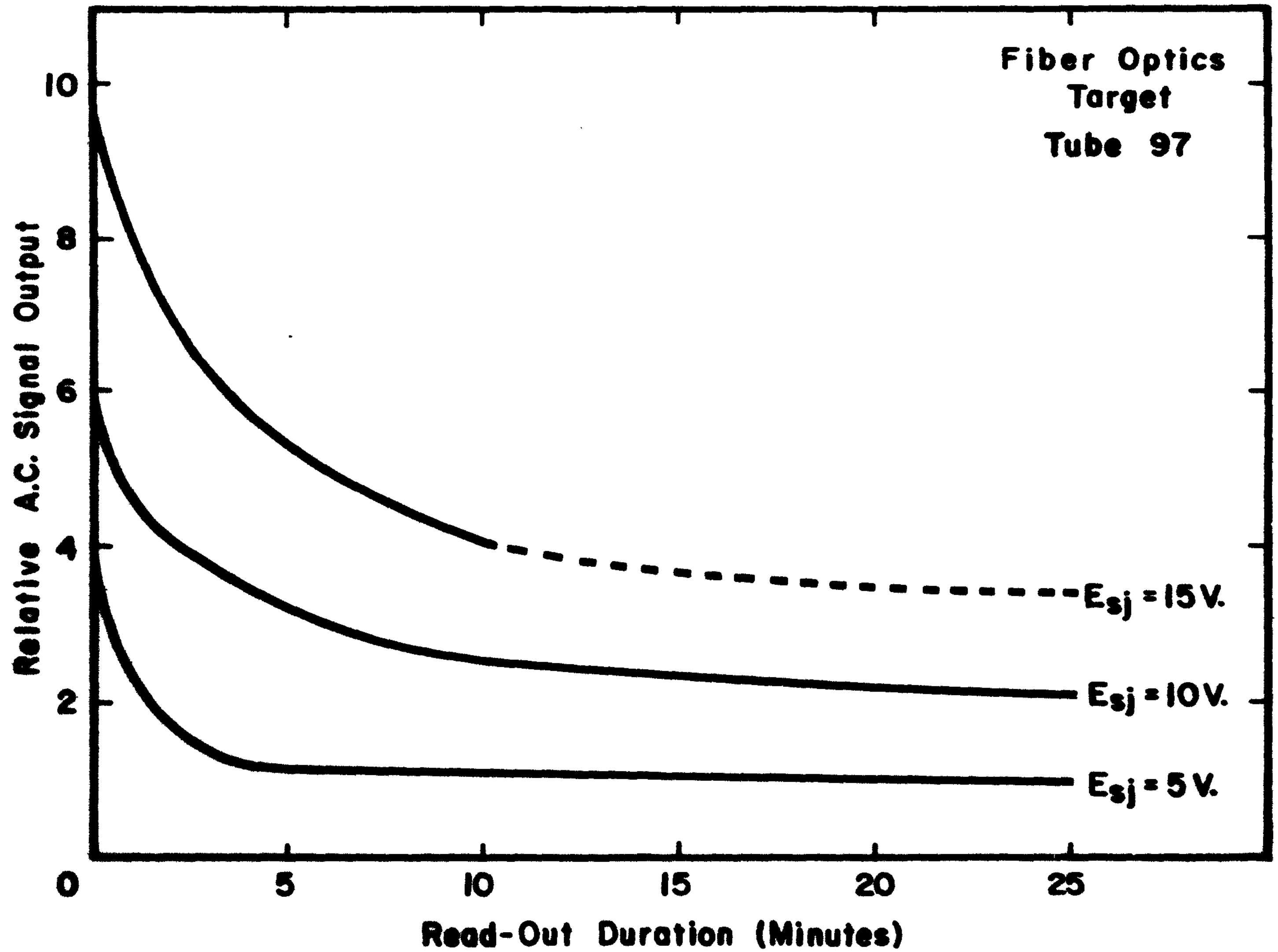
The storage characteristic of tube 97 at different target voltages is given in Figure 19. The storage characteristic of tube 95 was very similar to this, except that lower dark-current caused less distortion in the output signal at the higher target voltages. The dark-current build-ups at different target voltages are plotted in Figure 20 for tube 95 and Figure 21 for tube 97. The dark current in tube 97 is more than twice that in tube 95, and it is thought that this is due to the higher resistance of the stannic oxide under the photoconductor in tube 97.

As shown in Figure 19, there is an initial decay of the



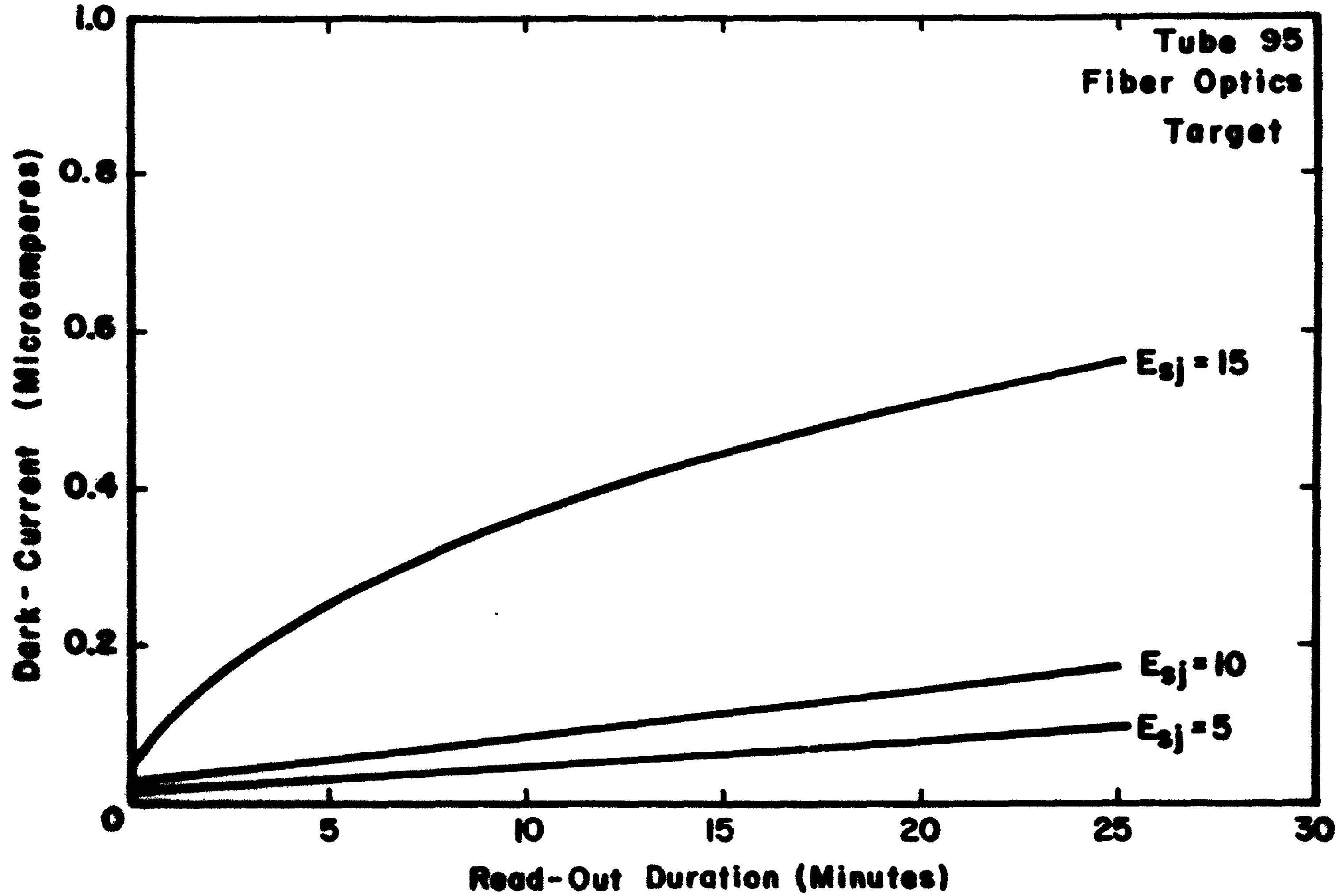
WRITING CHARACTERISTIC

FIGURE 18



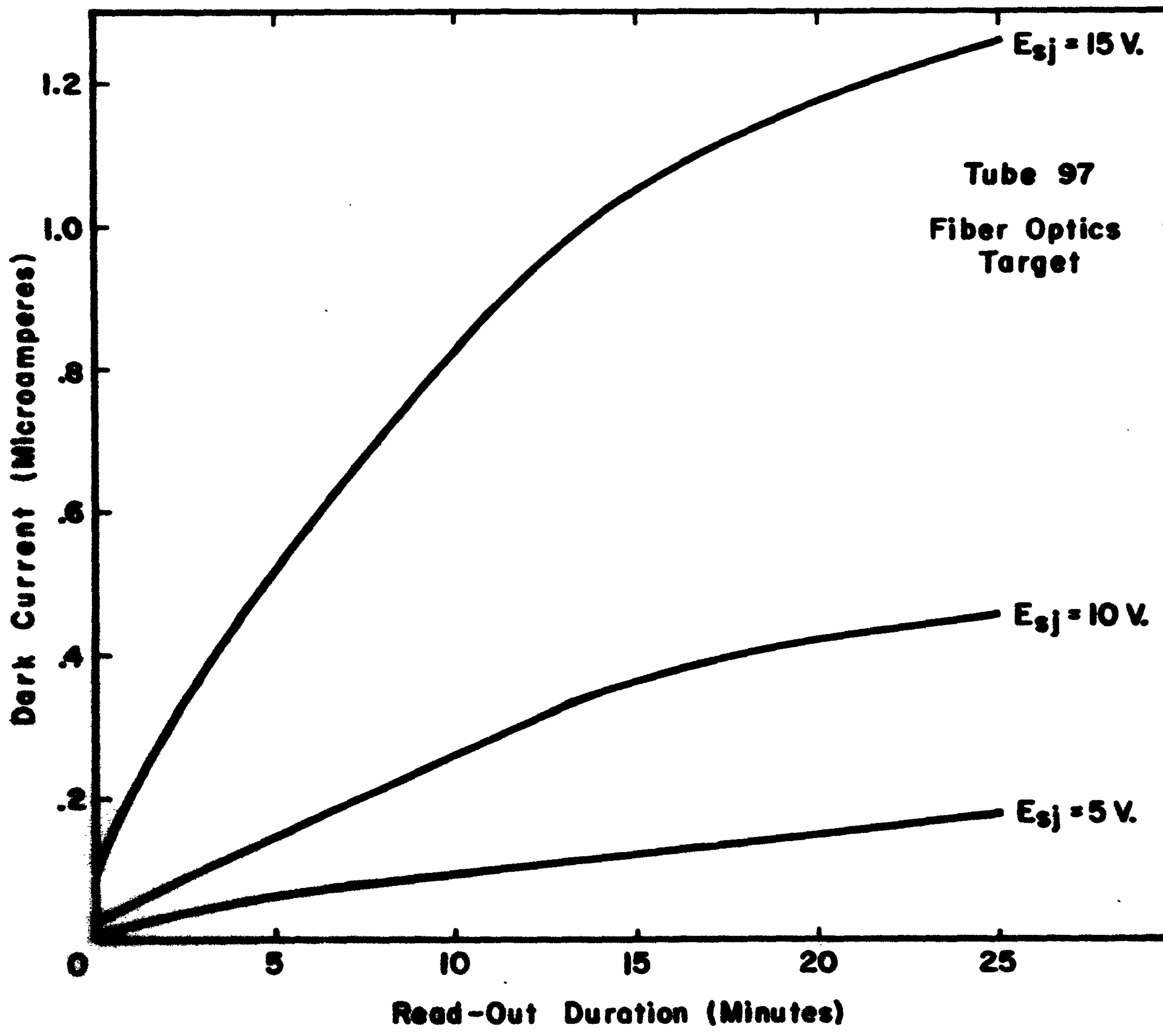
STORAGE CHARACTERISTIC

FIGURE 19



DARK-CURRENT CHARACTERISTIC

FIGURE 20



DARK CURRENT CHARACTERISTIC

FIGURE 21

stored signal for five to ten minutes, after which time the signal remains nearly constant. The dashed portion of the curve indicates the storage time during which the output signal is grossly distorted by dark-current build-up.

Dark-current build-up is one of the most serious obstacles to long storage at the higher target voltages.

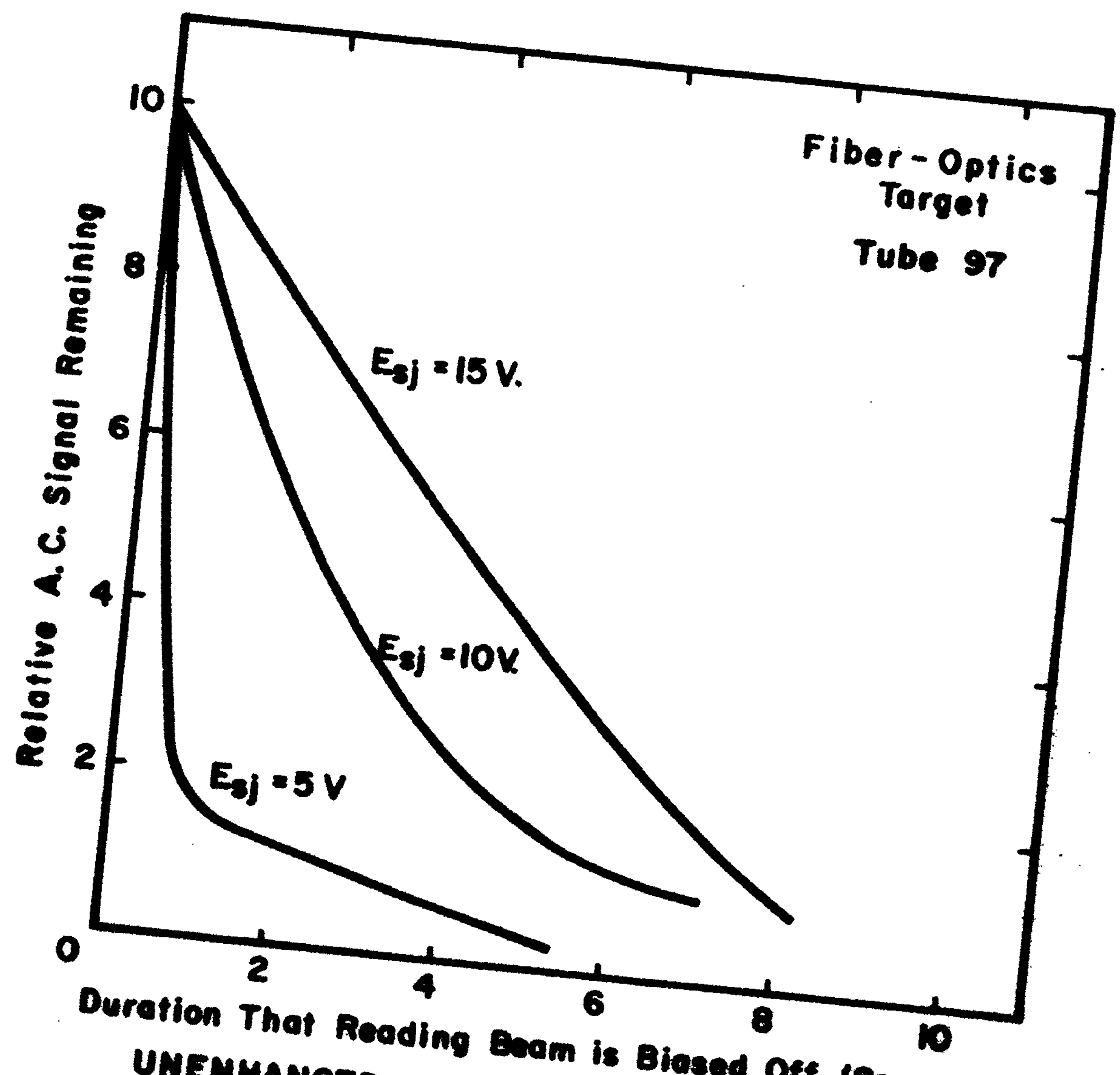
Erasure

Experiments were performed with tubes 95 and 97 to determine the speed of erasure. Figure 22 indicates the time required to remove stored signals from tube 97 at different target voltages by means of unenhanced erase, i.e., just biasing off the read-gun electron beam. When the writing beam was allowed to illuminate the phosphor during the period in which the read-beam is biased off (enhanced erasure), the stored signal was reduced to zero in less than two seconds, which is markedly faster than when unenhanced erasure is used. Tube 95 gave similar results. At this time an equipment limitation prevents enhanced erasure of shorter duration.

Resolution

The limiting resolution of the latest scan-converters with FOPT targets was 350 TV lines.

To determine the resolution capability of the target itself,



UNENHANCED ERASURE CHARACTERISTIC

FIGURE 22

detailed photomicrography was performed. The investigations were performed using the USAF 1951 Resolution Chart, a Leitz Ortholux Microscope with a blue-filtered light source, and panatomic-X film developed in Microdol-X for fine-grain resolution. The magnification to the film is 42X, and the group identification numbers have been touched up for ease of identification.

Figure 23 is the "aerial image" from the test pattern, which indicates 11,600 TV-lines-per-inch. Figure 24 is a photomicrograph of the pattern transferred through a polished 10-micron-pitch fiber-optics disc. The fiber-optics disc in contact with pattern limits the resolution to 2900 TV-lines-per-inch. To determine the effects of the stannic oxide coatings, the disc was coated on one side and again placed on top of the resolution pattern. Figure 25 was made with the coated side in contact with the pattern, and Figure 26 with the coated side opposite. In both cases the resolution was limited to 2290 TV-lines-per-inch. An additional lamina of stannic oxide was deposited on the referse side of the fiber-optics disc, and Figure 27 is the resulting resolution pattern. The resolution was reduced to 2040 TV-lines-per-inch by the second layer. Figure 28 was the final photomicrograph taken of the target with one side coated with a P-11 phosphor. The phosphor in contact with the test pattern reduces the resolution to 1780 TV-lines-per-inch. These results indicate that the resolution of the tube is not yet limited by the fiber-optics.

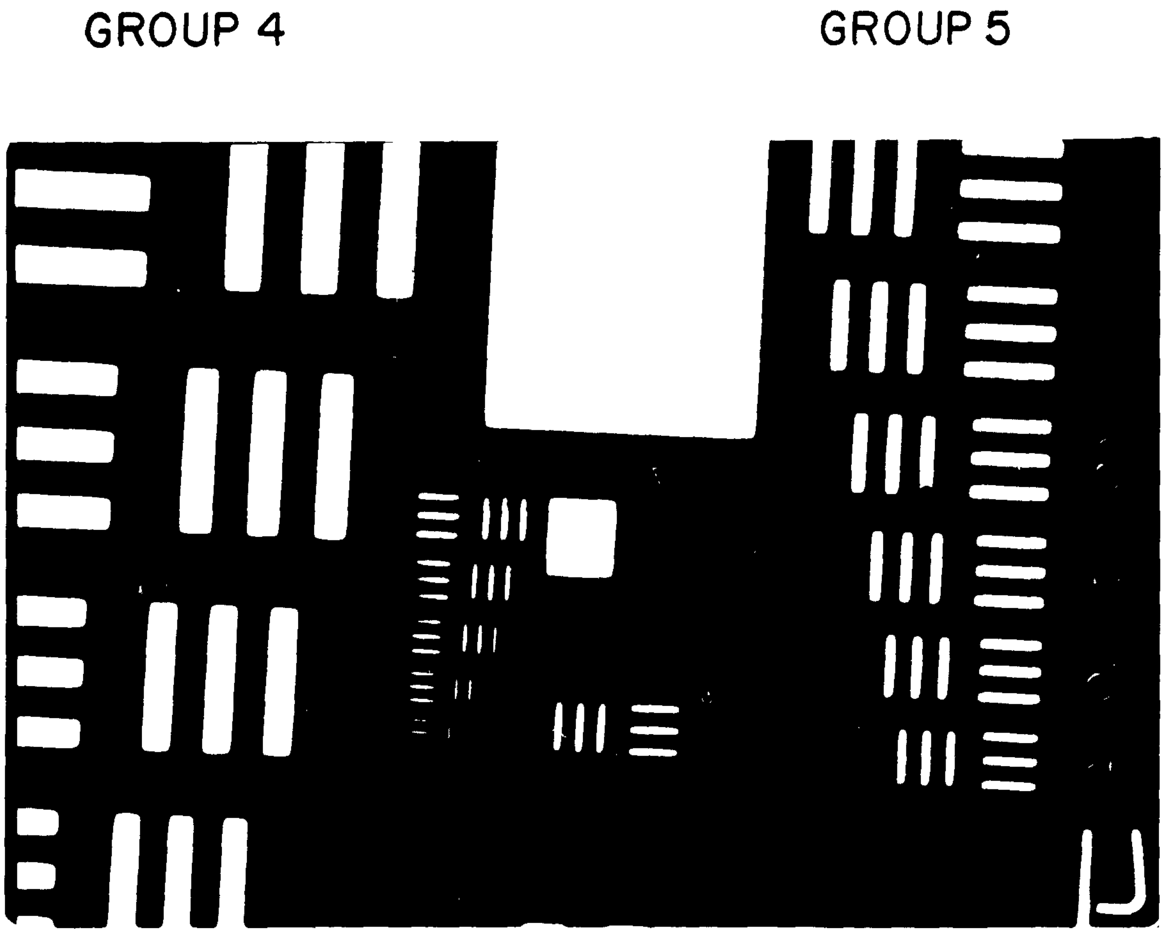


Figure 23 Aerial image USAF resolution pattern (42X).

GROUP 4 GROUP 5

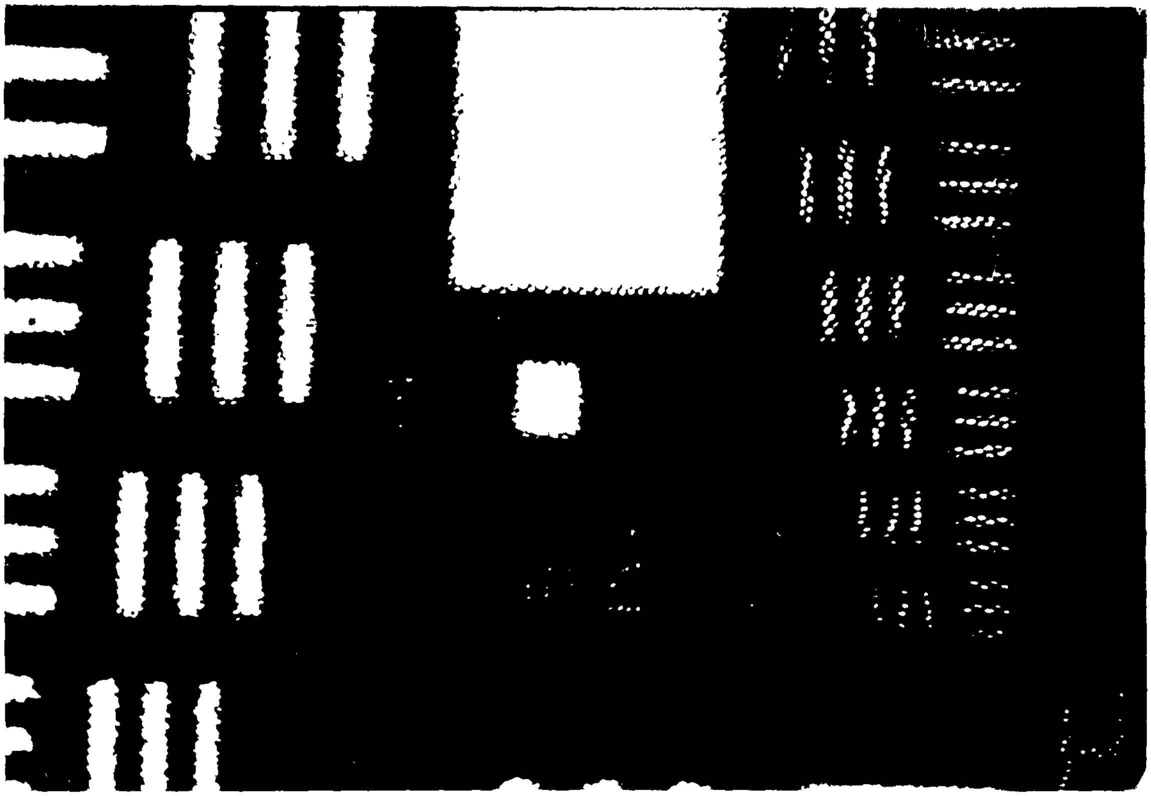


Figure 24 Resolution pattern through a 10-micron-pitch fiber-optics disc.

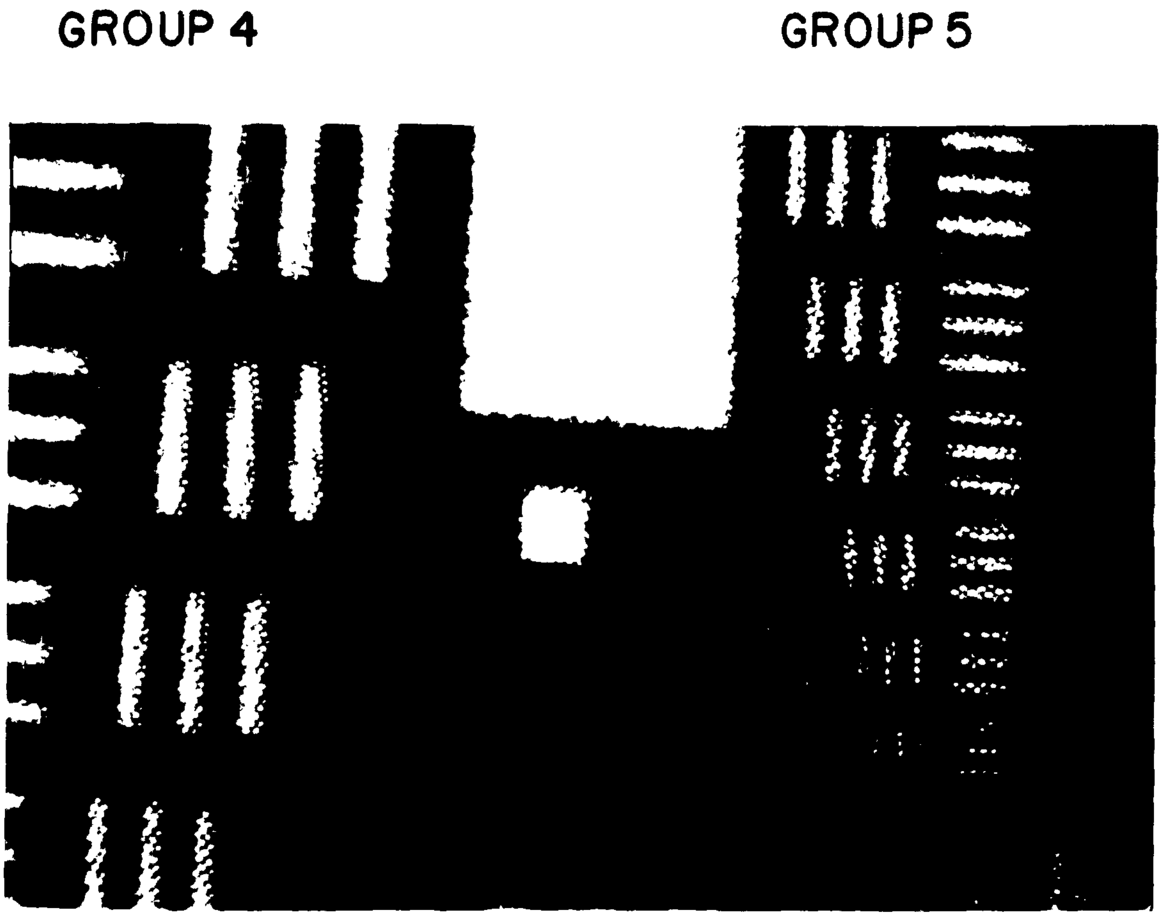


Figure 25 Resolution pattern through coated fiber-optics, coated side down.

GROUP 4 GROUP 5

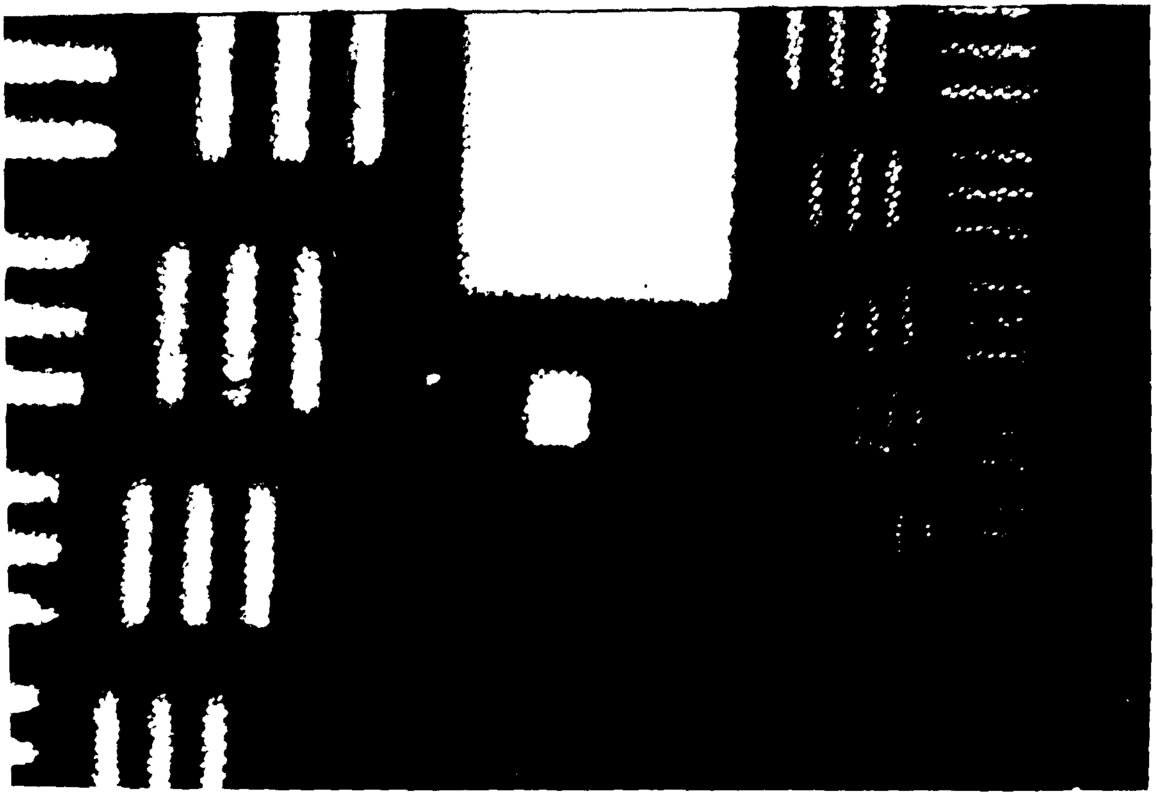


Figure 26 Resolution pattern through coated fiber-optics, coated side up.

GROUP 4 GROUP 5

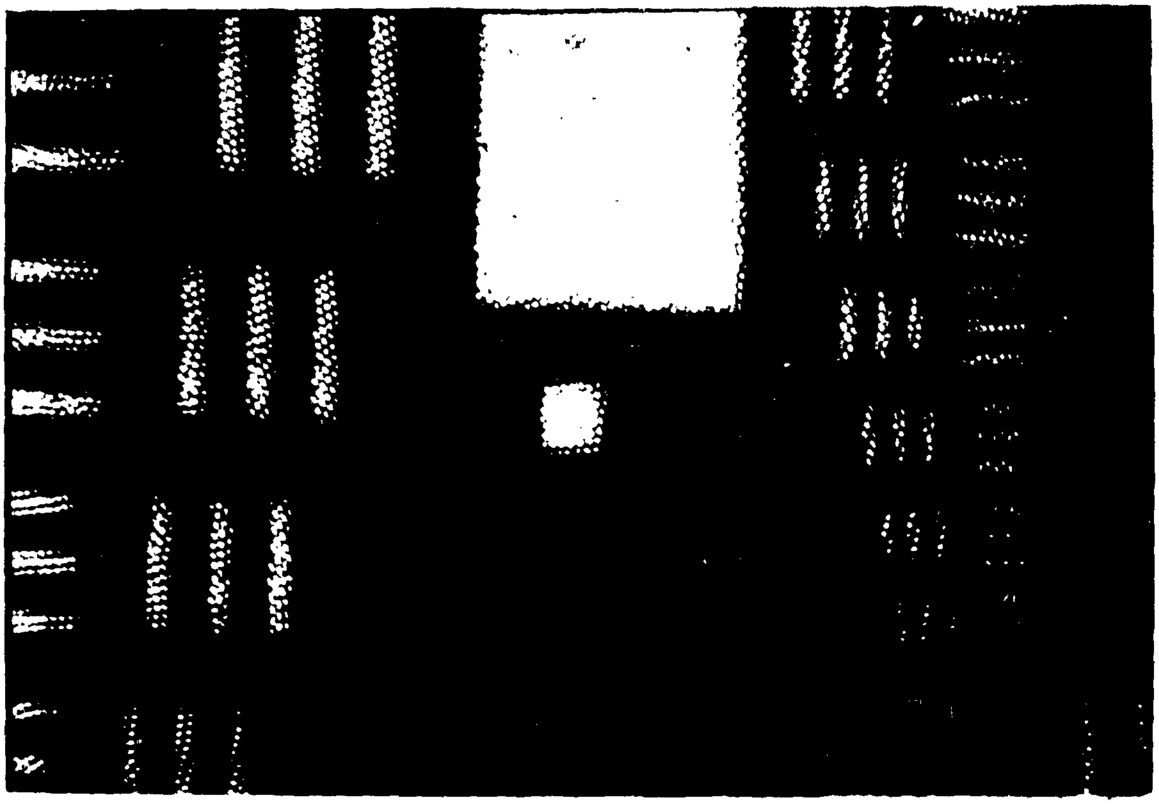


Figure 27 Resolution pattern through fiber-optics coated on both sides.

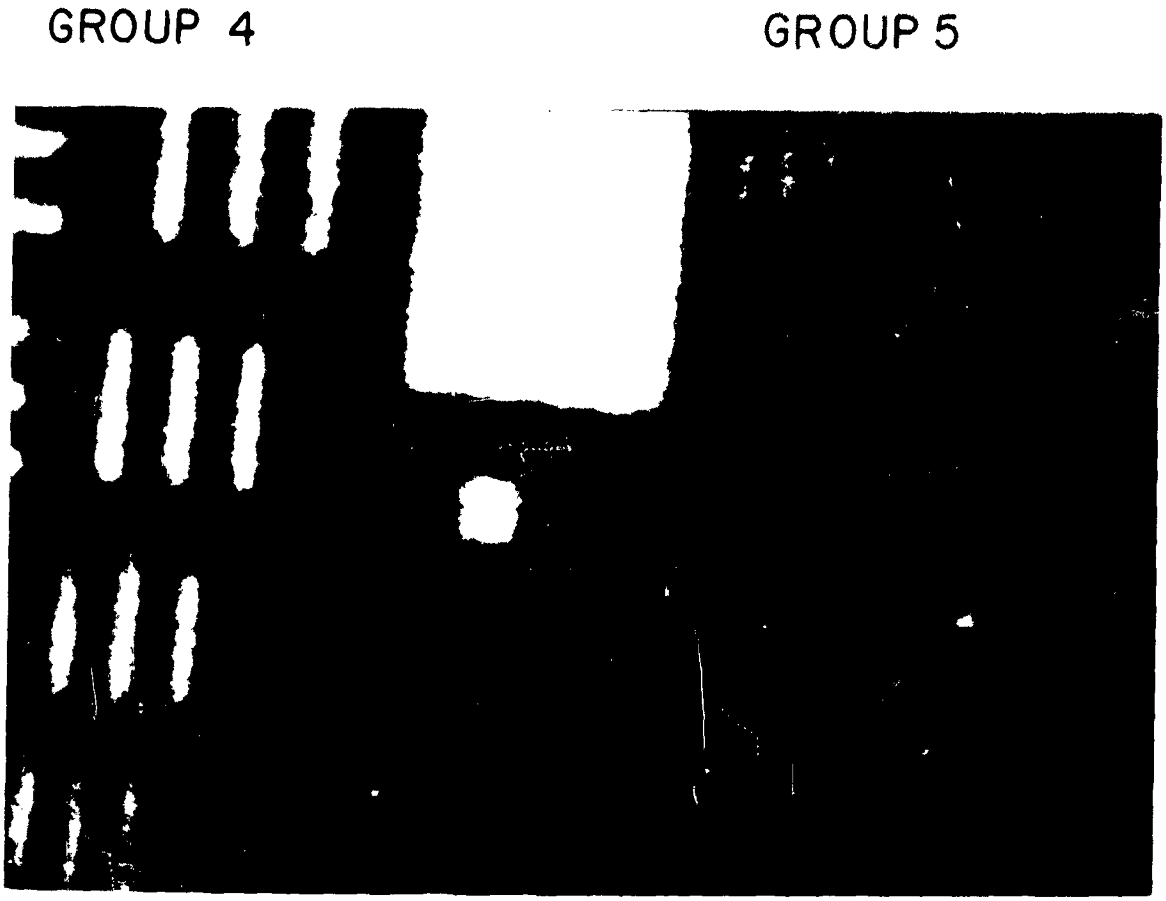


Figure 28 Resolution pattern through fiber-optics with coatings and P-11 phosphor.

This target is scheduled to be built in a single-gun tube with a 7056 glass faceplate that will make it possible to observe an electronically written resolution pattern through the fiber-optics.

OVERALL CONCLUSIONS

In the final analysis, this contract has shown conclusively that a scan-conversion storage tube can be made that will embody the characteristics of the Permachon-type vidicon.

Two basic types of targets were investigated, those based on Electron-Bombardment-Induced-Conductivity, and those based on Fiber-Optics Photon Transfer. The many tests and experiments performed indicate that the FOPT approach is the more flexible and the more successful. Too many factors are yet undetermined in the EBIC mode of Permachon operation, while the FOPT approach makes use of the technology gained from the development of the Permachon camera storage tube.

The resolution of the tube is limited by the diameter of the electron beam and the size of the target.

High dark-current in many of the FOPT tubes is caused by the radiation from the cathodes and heaters and by the high resistance of the transparent conductive laminae.

Fiber-optics discs that are suitable for the construction of a FOPT scan-converter target can be obtained commercially.

An envelope-and-target-mounting structure which is rugged and reliable has been developed.

REFERENCES

1. J. F. Nicholson, "Permachon - A Storage Pickup Tube," IRE Transactions on Electron Devices, April, 1960, p. 113.

2. J. F. Nicholson, "Storage System," U. S. Patent No. 3,046,431.

3. J. F. Nicholson, "Photoconductive Target," U. S. Patent No. 3,020,442.

RECOMMENDATIONS

It is recommended that the development of the scan-conversion tube be continued and that the program be focused on the FOPT-type target.

Work should be devoted to improving tube performance in the following areas:

1. Stored-Signal Retention

   This factor can be studied using various photoconductors and methods of deposition.

2. Erasure Speed

   The equipment should be further automated to make possible more rapid enhanced erasure.

3. Dark-Current Suppression

   Various substrates can be investigated, and new methods for depositing stannic-oxide should be developed.

4. Writing Speed

   The transfer efficiency of the target can be increased by using different photoconductors and by aluminizing the phosphors.

5. Resolution

   Particular attention should be given to this factor. One major step toward the increase in resolution will be to increase the target diameter. This will also minimize the effect of tiny fiber-optics blemishes and imperfections upon the output presentation.

To make the tube more useful in applications where size, weight, and power consumption are considerations, electrostatic electron optics should be included.

PERSONNEL

During the period of this contract, approximately 15,796 engineering man-hours were devoted to the design and development of the scan-conversion storage tube based upon the Permachon camera storage tube. Approximately 1,172 hours of this time were applied during the tenth quarterly period. A list of the persons who contributed to this effort is supplied below, and biographies of the key personnel involved are included on the following pages.

Engineers	Tenth Quarter	Entire Contract
G. M. Bernhardt		125
L. G. Bonney		810
R. P. Carpentier		4
R. H. Clayton		24
G. Cox		6
R. J. Doyle	400	1,211
G. L. McCurdy		35
W. L. Plummer		27
W. S. Rial		2,542
E. E. Selby	3	40
R. A. Shaffer	19	175
R. A. Simms		688
V. Upshaw		136

R. Van den Heuvel	—		2,160	
	422		7,983 Hours	
Technicians				
G. G. Gresock	291		291	
R. G. Hovis	344		1,072	
Others	115		6,450	
	750		7,813 Hours	
Totals		1,172		15,796

Approved by:

R. A. Shaffer
Supervisory Engineer
Image Tube Department

Submitted by:

R. J. Doyle
Project Engineer
Image Tube Department

Leo G. Bonney, Jr.

Education

Lehigh University, B.S. in Chemical Engineering, 1958
Cornell University, 1 semester toward Ph.D in Inorganic Chem., 1959

Professional Experience

1958 - 1959 - Cornell University, Ithaca, New York. Teaching Assistant in Freshman Chemistry.

1959 - date - Electronic Tube Division of Westinghouse Electric Corporation, Elmira, New York - Chemist, Camera Tube Engineering Section.

Accomplishments

Co-submission 7 disclosures in 3-1/2 years of employment; 4 on storage targets and one Most Meritorous Award for a disclosure concerning the storage orthicon; 2 on scan converter targets.

Recognition

Tau Beta Pi, Pi Mu Epsilon, teaching assistantship at Cornell University, Bradford County Scholarship, American Viscose Corp. Scholarship.

Affiliations

American Chemical Society

Robert J. Doyle

Education

Northeastern University, B.S. in Electrical Engineering, 1959

Professional Experience

1955-1959 - Raytheon Company, Microwave and Power Tube Division
Development of microwave and storage tubes.

Since 1961 - Westinghouse Electronic Tube Division. Development of image tubes.

Military Service

1959-1960 - U. S. Army Signal Corps, Fort Monmouth, New Jersey.
Microwave Tube Branch of USASRDL. Research into microwave devices.

Affiliations

Member of the IEEE

Wayne S. Rial

Education

Indiana Technical College, B.S. in Radio Engineering, Nov. 1954

Professional Experience

Jan. 1955 - date - Electronic Tube Division of Westinghouse Electric Corporation, Elmira, New York. Electronic Engineer. 3 years on receiving tube application, 2 years on storage tube test systems, 3 years on image tube test systems and applications.

Military Service

May 1944 - Nov. 1951 - U. S. Navy. Maintenance of all types of shipboard electronic equipment.

Accomplishments

One patent issued in 1950. 12 disclosures have been submitted on receiving tube application, 9 on Image and Storage Tube devices and applications.

Seven technical articles have been published in trade journals.

Chairman of Advisory Group to JETEC 5.4
January 1957 to January 1958

Affiliations

Member Grade IEEE

Robert A. Shaffer

Education

Colgate University, B. A., 1950
Air Force Eelectronic Schools

Professional Experience

Since 1954 - Electronic Tube Division of Westinghouse Electric Corporation, Elmira, N. Y. Engineer, Cathode Ray Tube and Image Tube Development Sections specializing in development of thin film techniques, secondary emission surfaces, and electroformation techniques. Project engineer and Supervisory Engineer of Image Orthicons and Allied Types.

Military Service

1950 - 1954 - U. S. Air Force. Third & Fourth Echelon Maintenance of Radar, Radio, Navigational Test Equipment.

Accomplishments

Patent on Technique for producing a fine mesh pattern on a substrate. Co-submission of 4 disclosures on storage targets.

Patent on an electron discharge device (electron gun modification)

Eight disclosures accepted on thin film and electroforming techniques. Three disclosures are in process.

Developed techniques for making thin films, for electroformation of fine mesh structures, for secondary emission surfaces, and for specialized vacuum evaporations.

Most meritorious disclosure award for thin film orthicon target.

Three engineering reports on electroformation of fine mesh structures.

Development of thin film target image orthicon and intensifier image orthicon.

Affiliations

Member of Alpha Chi Sigma

Robert A. Simms

Mr. Simms graduated from the Milwaukee School of Engineering with a Bachelor of Science Degree in Electrical Engineering in March, 1959.

While pursuing graduate studies at Marquette University, he taught physics at the Junior grade level at the Milwaukee School of Engineering.

Mr. Simms joined the Electronic Tube Division of the Westinghouse Electric Corporation in July 1960. Since that time he has been principally engaged in photoconductive studies. He is continuing his graduate work at Cornell.

Raymond C. Van den Heuvel

Born of European parents in Mbigo (Rutshuru) in the Kivu Province, Belgian Congo, Mr. Van den Heuvel received his education in the United States at Milwaukee School of Engineering, graduating in June of 1960 with a bachelor's degree in electrical engineering.

In July 1960, Mr. Van den Heuvel joined the Camera Tube Engineering Department of the Westinghouse Electric Corporation.* His duties as junior engineer were on camera tube design problems, particularly scan-converter tube design.

Mr. Van den Heuvel continued studies towards a master's degree in electrical engineering at Cornell University.

Mr. Van den Heuvel is an associate member of the A.I.E.E.

*Has since left the employ of Westinghouse.

CONTRACT DA36-039-sc-85051
Westinghouse Electric Corporation

Final Report
1 July 1960 to
31 December 1962

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Director, Fort Monmouth Office USA Communication & Electronics Combat Development Agency Fort Monmouth, New Jersey	1

This contract is supervised by the Special Tubes Branch, Electron Tubes Division, Electronic Components Department, USAELRDL, Fort Monmouth, N.J. For further technical information contact:

Mr. Munsey E. Crost ______________ Project Advisor

Pickup, Display, and Storage Devices ______ Section, Tel 201 5961102

AD ______________________ Accession No. ________

Camera Tube Dept., Westinghouse Electric Corp.
Elmira, New York

SCAN-CONVERSION STORAGE TUBE BASED UPON THE PERMACHON - R. J. Doyle

Final Progress Report, 1 July 1960 to 31 December 1962, 60 pp - 28 Ill. DA Contract DA36-039-sc-85051 Task No. 3A99-13-003-03 Unclassified Report

A scan-conversion tube based upon the storage characteristics of the Permachon camera storage tube was developed by the Westinghouse Electric Corporation under this contract from the United States Army Electronics Research and Development Laboratory. The tube consists of three major components; a reading electron gun, a writing electron gun, and an interjacent scan-conversion target.

Two types of targets were investigated for use in the tube, these based upon: 1. Electron Bombardment Induced Conductivity (EBIC), 2. Fiber Optics Photon Transfer (FOPT).

(Over)

Unclassified

1. Electron Tubes
2. Storage Tubes
   Electrical-Signal
   Multi-Gun
   Permachon Principles

I. Doyle, R. J.
II. U. S. Army Electronics Research & Development Lab., Fort Monmouth, N. J.
III. DA Contract DA36-039-sc-85051

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Two types of targets were investigated for use in the tube, these based upon: 1. Electron Bombardment Induced Conductivity (EBIC), 2. Fiber Optics Photon Transfer (FOPT).

(Over)

The EBIC targets, in general, did not exhibit the storage, signal integration, and erasure characteristics of the Permachon storage surface, and except for the aluminum-supported EBIC targets, high dark-current was a major problem.

The FOPT target, on the other hand, did perform similarly to a Permachon storage surface, and details of the characteristics of these targets are included in this report.

The final scan-conversion tube developed is 16 inches long; the read-gun is similar to a low-velocity vidicon gun; the write-gun is a high-velocity cathode-ray-tube gun; and the target is that based upon FOPT.

Because the written and read-out signals are isolated by the glass fiber-optics disc, no rf or other video-canceling circuitry is required for the operation of the tube.

The EBIC targets, in general, did not exhibit the storage, signal integration, and erasure characteristics of the Permachon storage surface, and except for the aluminum-supported EBIC targets, high dark-current was a major problem.

The FOPT target, on the other hand, did perform similarly to a Permachon storage surface, and details of the characteristics of these targets are included in this report.

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